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Technological Advance and Organizational Innovation in the Engineering Industry

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TECHNOLOGICAL ADVANCE AND ORGANIZATIONAL INNOVATION IN THE ENGINEERING INDUSTRY

A New Perspective on the Problems and Possibilities for Developing Countries

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INTRODUCTION

i. The engineering sector, and industry generally, is engaged in a process of fundamental structural, organizational, and technological transformation. The key features of this transformation are growing flexibility, greater diversity, declining product and, conceivably, plant scale economies and, ultimately, quantum leaps in productivity. These developments presage a much tougher competitive environment domestically and internationally in the engineering sector.

ii. The leading edge of this transformation currently is centered in the advanced industrial economies, but the changes will have implications for all countries. The dominant technical factor at work in this process is the development and diffusion of a family of automation technologies, flexible manufacturing techniques, and new products deriving from computer-based control and communication systems.[1/] These innovations are generic, highly adaptable, and thus applicable to virtually every segment of the engineering subsector. The considerable technical and economic advantages arising from their successful adoption give significant competitive gains to user firms.

iii. Although most change in production technology so far has involved the introduction of individual automation technologies (e.g., CAD systems, CNC machine tools) on a stand-alone or island basis, the trend toward integration of different components into more flexible manufacturing systems (FMS) is well-established. The significance of this trend is that the gains attainable through systemic integration are considerably greater than those from stand-alone automation technologies.

iv. Although the technology factor is clearly a major stimulus for change in the engineering subsector, other developments are beginning to play an equally important part in the transformation. Perhaps the most important are the organizational innovations associated with concepts such as just-in-time (JIT) inventory control, total quality control, and total preventive maintenance, which are spreading rapidly through the engineering sector at inter-firm and intra-firm levels. Much of Japan's early international economic success in engineering and other sectors is attributed to the competitive advantages Japanese firms gained from their persistent efforts to apply these principles to the organization and management of production from the 1950s through the 1970s. In fact, many of the so-called "new management practices" originated earlier in the U.S., where they were never adopted widely. Regardless of their historical origins, these organizational innovations represent a sharp departure from the conventional management practices historically followed by Western firms--many of whom now appreciate that their future competitive success will depend on successful adoption of "new" systems. Indeed, a firm's capacity for introducing organizational change has

1/ Simultaneously, other technological breakthroughs are finding widespread use throughout the sector in both process (e.g., lasers) and product (e.g., new materials) applications. Eventually the technical and economic effects of these innovations will be substantial. Commercial introduction of these technologies is at too early a stage for predictions regarding their eventual impact; they will not be discussed in this paper.

emerged unexpectedly as perhaps the most critical determinant of its success in using advanced flexible manufacturing techniques effectively.

v. There is a growing consensus that the combination of flexible manufacturing technologies and new forms of production management constitutes a new "best-practice" system of manufacturing that will replace conventional approaches in much the same way that mass production replaced craft-based methods in the nineteenth century. The diffusion of new organizational and technological innovations is affecting the dynamics and structure of the engineering industry within the industrialized countries and in the process is altering barriers to entry and competitiveness at national and international levels. Because of the engineering sector's vital role in industrial development, the profound technological changes taking place are particularly relevant for countries on the threshold of industrialization.

vi. In many respects, the changes underway in engineering are part of a much broader process of change in the global industrial system. This is manifested at the micro-level in the rapid cross-sectoral diffusion of the new techniques, as well as in the related rise of Japan as a dominant industrial power--intent on changing the "rules of the game" of global competition--and the response of the U.S. and European firms to this challenge. The engineering sector represents a laboratory where the elements of the new technological and organizational paradigm are being tested and perfected.[2/]

vii. This paper is part of work on technology change by the Industry Development Division of PPR-the World Bank. The first chapter looks at the current pattern of technological change in the engineering sector, concentrating primarily on the nature and impact of what are called flexible manufacturing systems. Though not at the leading edge of computer-integrated manufacturing, FMS represent a significant advance in integration and flexibility over previous generations of automation technology and are becoming central to innovation and competition in the sector.

viii. Although the pattern and effects of information technology on manufacturing applications have been a dominant focus of industrial analysis, appreciation of the significance of organizational innovations is more recent. Chapters II and III explore how organizational change is becoming a key determinant of a firm's competitiveness in the engineering sector and in

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2/ For this paper we consider the engineering sector in its widest sense as essentially including all industries based primarily on metal working, thus a range of sectors and firms that exhibit enormous diversity. The products involved range from simple gears or valves to extremely complex multi-component products such as automobiles and aerospace engines; the scale of production varies from millions of identical products to limited runs of special purpose items; the complexity of the production process spans the gamut from unsophisticated one-step stamping operations to multi-stage processes requiring extremely fine tolerance and control procedures; and finally, we include capital goods firms, as well as producers of intermediates and final products, with the size of these firms varying from fewer than 50 employees to more than 100,000.

manufacturing generally. Chapter II discusses the growing consensus about the significance of the new practices, reviews evidence of their impact across sectors and countries, and provides an empirical foundation for the analysis that follows. It also explores the new organizational and managerial approaches, how they work, and the problems encountered in their introduction. Chapter III reviews the operational techniques firms use to bring the general principles into practice and gives an impression of how these techniques operate in practice, noting some indications of their productive applicability in developing countries. Chapter IV also focuses on issues related to the applicability of the new organizational practices in developing countries. The objective of the chapter is to encourage further examination of the issues on the grounds that the possibility of introducing these organizational methods could be one of the most important challenges and opportunities for industrial progress now confronting developing countries.

I. SYSTEMIC AND FLEXIBLE AUTOMATION IN THE ENGINEERING SECTOR

The Problems of Batch Production in the Engineering Sector

1.01 In advanced industrial economies, firms operating in most segments of the engineering sector face the dilemma of sacrificing the economic advantages of high volume and long production runs to maintain flexibility for producing relatively small batches of output. With the emergence of a powerful range of new technologies based on programmable automation, the engineering industry is moving into an era when the trade-off between flexibility and scale will not be necessary. Before discussing the benefits from this advance, this chapter characterizes the production process in engineering and identifies areas where flexible automation technologies are beginning to have a major effect.

1.02 Engineering production falls into three categories: mass production of standardized products, with tens of thousands of units manufactured per year; batch production involving annual volume from tens to thousands of units; and production of small lots, one-off items, and prototypes. In the past, producers in each segment evolved a manufacturing technology suitable to their conditions of production and competition. Mass production firms relied heavily on automated transfer lines and costly dedicated equipment operated at high capacity and capable of garnering impressive scale economies. Producers of one-offs and prototypes, meanwhile, were able to use a highly skilled workforce in conjunction with flexible machines to create great product variety at very low levels of output.

1.03 These two groups of firms were among the first in the engineering industry to benefit from the application of microelectronics to manufacturing technology--high volume firms, from the further automation of their dedicated production lines; and small batch firms involved in prototype production, from computer-numerical control (CNC) of individual machine tools.

1.04 Firms engaged in the middle area of batch production [3/] faced a far more difficult task in coping with the demands of their markets. Volumes were too low to use dedicated machinery and too large for single machines. Confronted with the need to produce a large range of products at highly variable levels of output, batch producers constantly traded volume production for flexibility. This accounts for the basic production setup still in place among most engineering firms: a variety of function-specific, stand-alone,

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3/ These firms account for a large majority of output in the engineering industry where, on average, 70% of components are produced in batches of less than fifty. Much of this batch work is done by small firms. Brandt (1986) estimates that the 100,000 small job shops in the U.S. engineering industry supply 75% of all the machined parts used by larger engineering firms. See also the further discussion of the U.S. case in Computerized Manufacturing Automation, Office of Technology Assessment, Washington, D.C. (1984); and NEDO (1984) for the U.K.

manually operated machine tools organized in a multi-step, discrete manufacturing process.

1.05 The necessity of producing in batch lots--with varying quantities and specifications--created complications in forecasting sales, ordering raw materials, balancing, tracking, and in choosing among many possible, but non-optimal production routes. The level of automation attainable under these conditions was low, and batch production firms never were able to capture substantial scale economies. In addition, a range of other problems plagued these firms and imposed costs in efficiency, capacity, and competitiveness:

- Frequent breakdowns of machinery, poor maintenance procedures, and long set-up and changeover times between product changes meant low capacity utilization;
- Bottlenecks and queueing problems;
- Large inventories of raw materials, work-in-progress, and finished goods;
- Long lead times in design, production, and product launch;
- Poor production control leading to excessive scrap and waste;
- Inconsistent quality and high rejection rates;
- High production and management overhead; and
- Poor delivery.

1.06 Because of these problems, in the typical U.S. engineering firm in the 1970s, machinery stood idle 70-95% of available production time, with value-added operations on the product accounting for only 2% of the time in the factory. More significant, between 50-70% of total product costs can be tied up in materials inventory and other overheads. For example, in the U.K. engineering industry, this accounted for the estimated US$37 billion in inventory and work-in-progress in 1986.[4/]

1.07 Through the end of the 1970s and into the 1980s, the competitive pressure on engineering firms began to change due to market entry by low-cost competitors, changing consumer preference, the recession, etc. These pressures translated into demands for lower prices, shorter production cycles, quicker delivery/response, and greater emphasis on design, quality, and customization (see Table 1.1). These problems require solutions that allow the attainment of both high productivity and high flexibility--a set of

4/ Ayers and Miller (1984); and Bessant and Heywood (1986). The discussion on production problems facing engineering firms draws on the work of Bessant (1985), Bessant and Heywood (1986), and Bessant and Rush (1987).

characteristics that has come to be associated with the phrase "manufacturing agility".5/

Table 1.1: MANUFACTURING FUTURES SURVEY (1986)
(List of competitive priorities in order of importance)

Europe	USA	Japan
Consistent quality	Consistent quality	Low prices
High performance	High performance	Rapid design changes
Dependable deliveries	Dependable deliveries	Consistent quality
Fast deliveries	Low prices	Dependable deliveries
Low prices	Fast deliveries	Rapid volume changes
After-sales service	After-sales service	Fast deliveries
Rapid volume changes	Rapid volume changes	After-sales service

Source: 1986 INSEAD survey of senior management of 500 top manufacturing firms; cited in Bessant and Rush (1987), p.4

1.08 The ability of the engineering industry to respond to pressures for production flexibility had been inhibited until recently by the limitations of existing technology, though partial solutions were possible (i.e. the use of CNC tools or Group Technology). The recent availability of technical solutions (based on integrated production systems) to the flexibility/cost conundrum coincides with pervasive market pressures for firms to adopt these solutions. This timely interaction of market demands and technology will remain an important force in the diffusion process in the engineering sector of the industrialized countries.

1.09 In turn, as discussed below, both the changing market conditions and the responses of engineering firms in industrialized countries to these changes will affect developing countries in major ways--in both export aspirations and in the organization and production for domestic markets.

Information Technology in Industry: Toward a Systemic Understanding

1.10 Microelectronics enjoys distinct economic and technical advantages over previous methods of information processing and control technology (manual, mechanical, electromechanical, and pneumatic). These advantages constitute an extremely powerful set of economic incentives that virtually compel the substitution of microelectronics-based systems for earlier

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5/ INSEAD (1987), cited in Bessant and Rush (1987). These trends are well developed in the motor vehicles sector and in a wide range of consumer products and high volume continuous processing industries such as petrochemicals, food processing, textiles and clothing. See Wyatt (1987) and "Microelectronics Monitor," issue 21, Fall 1987, UNIDO, Vienna, for a review.

systems.[6/] Because microelectronics can be used in all information-based activities, the technology can be introduced into virtually every aspect of a firm's operations--from production management, administration, design and process specification, and raw material processing, to packaging, testing and inspection of final products and manufacturing processes. Due to this flexibility, microelectronics, or information technology as it also is called, has found wide application across industries, within sectors, and within firms.[7/] This capacity of information technology to stimulate successive rounds of innovation outwardly lies at the heart of the so-called information technology revolution.[8/]

1.11 Of more direct interest is the following model of the progress of automation at firm level,[9/] which helps situate past and future developments in automation in a way that relates directly to current patterns of technical change in the engineering industry.

1.12 Figure 1.1 shows manufacturing divided into three distinct spheres of activity: design, production, and coordination, with each sphere comprising a set of discrete activities.[10/] Since the Industrial Revolution, there has been a gradual process of automation of individual activities, but rarely were discrete activities within spheres linked together, even in the mass production assembly lines with their fixed automation. The recent emergence of microelectronics, however, has stimulated a more pervasive process of activity-specific automation. This is occurring with different degrees of intensity and rapidity at three levels, as depicted in Figure 1.2.

6/ See Soete and Dosi (1983) for the clearest explanation of the technical advantages of microelectronics and their economic implications.

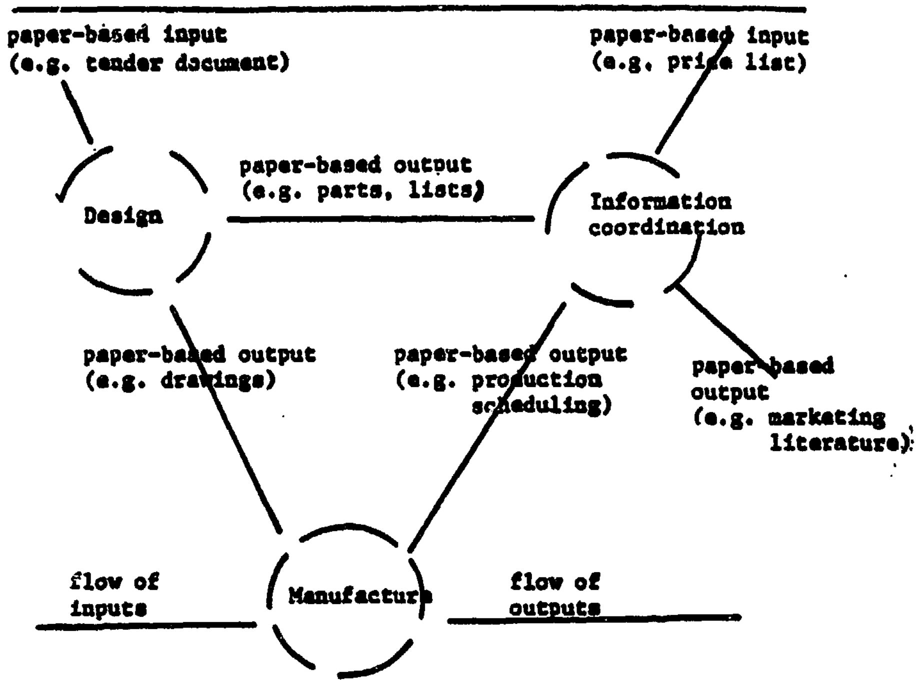
7/ See Hoffman (1986) for a review and references.

8/ The macro level effects of this technological revolution for the national and international economy and the implications for theory and policy have been widely debated and discussed in the literature. See Dickson and Marsh (1978); Hines and Searle (1979); ETUI (1983); Freeman, Clark and Soete (1982); Soete (1985); and Kaplinsky (1987) for early reviews and different perspectives. See James (1987) for extensive references and a critical discussion of the "impacts" literature.

9/ This model has been developed by Kaplinsky in a recent series of publications. See Kaplinsky (1984, 1985) for the initial presentation, and Hoffman and Kaplinsky (1988) for a revised version and empirical test.

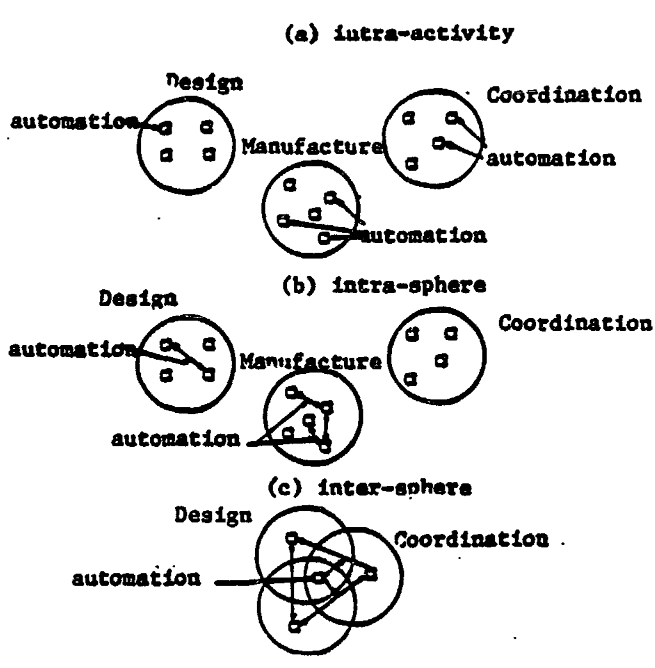
10/ Design activities include drafting, copying, basic and final design, process engineering. Production activities could be mixing, molding, cutting, handling, testing, packaging. Coordination involves all managerial tasks needed to support and guide the firm's operations internally and in the marketplace.

Figure 1.1 Pre-electronic Organization of Factory Production



Source: Kaplinsky (1985)

Figure 1.2 Three Levels of Automation



Source: Kaplinsky (1985)

1.13 The first level of intra-activity automation involves automation of individual activities in a stand-alone fashion; application of information technology has been concentrated at this level so far. The second level is intra-sphere automation; its key feature is the integration of individual activities within the same sphere. The third level is inter-sphere automation in which activities in separate spheres are integrated and coordinated via their common dependence on digital control systems.

1.14 The crucial components in this multi-stage advance of automation are a family of automation technologies that emerged early in the industrial application of microelectronics. Computer-aided design (CAD) is dominant in the design sphere. In manufacturing, computer-numerical control (CNC), applied initially to machine tools, was the earliest, followed by robots, programmable logic controllers, automated materials handling systems, and process controllers for real-time control of production. In the coordination sphere, centralized data processing and office technologies were first to have an impact on management.

1.15 As with microprocessors, these new technologies are highly flexible, with applications suitable for use in a number of sectors.[11/] User firms have been able to capture substantial technical and economic gains, and the pool of users has steadily increased as unit costs have declined and performance improved. These factors contributed to the rapid diffusion of automation technologies beginning in the late 1970s.[12/]

1.16 While the large-scale, mass production segment of the engineering industry uses CAD units and robots extensively;[13/] the sector has played a

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11/ Various issues of UNIDO's "Microelectronics Monitor" provide details of a wide range of applications for stand-alone automation technologies. See also Hoffman (1985).

12/ Sales of CAD systems grew 85% annually over 1978-82 and by 1985, some 27,000 firms used CAD systems worldwide. The CAD world market totaled about US$3.3 billion in 1986, with an expected annual growth rate of between 15% to 20% in the medium term. For industrial process controllers, U.S. demand has been growing at 30% annually; in 1985 some 115,000 programmable logic controllers were in use in FRG, France and England; 77,500 programmable robots were in use worldwide in 1984, with more than 140,000 "steel collar" workers in place in factories in Japan, Europe and the U.S. by 1986. Total 1986 sales of robots were about US$1.88 billion and are expected to nearly double to US$3.5 billion by 1990. U.S. Department of Commerce (1985) for CAD numbers; ECE (1986) for machining center figures; Northcott and Rogers (1985) for European figures; and UNIDO (1987) for robot figures. See also The Economist (1987) and Bessant and Rush (1987).

13/ Producers of design-intensive products in the aerospace sector (where CAD systems were first developed), such as Boeing, typically use many hundreds of CAD systems, while GM has some 200,000 programmable tools. The Economist (1987).

very important role in the development and diffusion of numerical control technology. Expanded demand for numerical control machine tools (NCMTs) has led to a large increase in the share of NCMTs in total production of machine tools throughout the OECD (Table 1.2). Table 1.3 shows that the engineering industry was the major user of NCMTs in the U.S. and Japan in the early 1980s. The growing intensity of NCMT use relative to conventional tools in the U.S. metalworking industry is indicated in the statistic that by 1983, approximately 103,000 NCMTs were in use.[14/]

Table 1.2: SHARE OF NCMTS IN TOTAL PRODUCTION OF SELECTED METALCUTTING MACHINE TOOLS IN OECD a/ (1976 and 1982)

	1976		1982		Growth Rate
	US$m	%	US$m	%	1976-1982
Boring machine					
NCMT	92	35	297	57	223
Conventional	171	65	226	43	32
Milling machines					
NCMT	145	23	633	53	337
Conventional	493	77	557	47	13
Drilling machines					
NCMT	34	13	93	34	173
Conventional	229	87	178	66	-22

a/ USA, Japan, FRG, France, Italy, UK

Source: Hoffman (1986)

14/ Large firms have always been major users of NCMTS, but smaller engineering enterprises have now become consistent investors in the new technology. Small firms with fewer than 100 employees accounted for about 40% of the U.S. stock of NCMTs in the early 1980s. In Japan, firms with fewer than 300 employees accounted for 62% of the investment of NCMTs in 1981. Jacobson (1985).

In NCMTs, unit price declines have been the result of declines in the cost of the CNC unit, which in 1985 was less than four times its cost in 1978. Likewise with CAD units: A typical workstation can cost from US$50,000 to US$125,000, but prices are now dropping to below US$20,000 and even US$10,000. Similar performance could be cited with regard to robots. NMTBA (1986); the Economist (1987); Electronics Week (July 1984).

Table 1.3: DISTRIBUTION OF NCMTS BY SECTORS IN JAPAN (1981) AND THE USA (1983)

	Japan a/	%	USA a/	%
General machine	11,394	43	52,541	51
Electrical machinery	4,262	16	10,772	10
Transport equipment	6,276	23	15,284	15
Precision machinery	1,775	7	4,874	5
Metal products	1,460	5	14,463 b/	14
Casting/forging products	580	2	2,662 c/	3
Miscellaneous	978	4	2,102	2
Total	26,175	100	103,308	100

a/ The Japanese inventory covers plants with 100 or more employees; the USA inventory covers plants of all sizes.
b/ Fabricated metal products
c/ Primary metals

Source: Hoffman (1986)

1.17 More recent data indicates that engineering firms of every size continue to invest in all aspects of automation technology. For instance, the most current annual survey of computer use in the U.K. engineering industry--based on a structured survey of over 2,000 firms--shows about 20% annual growth in overall applications of computer hardware and software between 1985 and 1987.[15/] In the U.S. 25% of companies planning to buy robots in 1986 had annual sales below US$10 million; with most of the firms involved in the production of machined metal parts. Computer purchase by small job-shop manufacturers are expected to increase by 35% a year through 1990.[16/]

1.18 In summary, the diffusion pattern for all three of the main automation techniques--NCMTs, CAD systems, and industrial robots--has followed the typical S-curve. NCMTs entered their growth phase in the mid-1970s and are now in their mature phase as evident in metal cutting activities where their penetration is greatest. NCMTs now account for over 76% of all production by value in the OECD countries, and small firms have accounted for well over 50% of investment in recent years.

1.19 CAD systems entered their growth phase in the 1982-84 period and will remain in this phase for some time. Their take-off was spurred particularly by the development of PC-based systems, which have registered annual

15/ Benchmark Research, Ltd., "Surveys of U.K. Computers in Engineering, 1985, 1986, 1987" as reported in Engineering Computers (1987), Findlay Publications, Horton Kirby, Kent. Cited in Bessant and Rush (1987).

16/ Brandt (1986).

sales increases above 70% since 1984.[17/] Finally, sales of industrial robots began to grow more rapidly in 1984/85. Annual investments in the OECD countries are now about US$1.5-$2.0 billion. Robots' growth phase is continuing, suggested by the growing investments by small firms and, more important, because robot applications have begun to move out of strictly welding operations and into assembly activities.[18/]

From Stand-alone (Islands) to Integrated Flexible Automation

1.20 Although automation technologies are undoubtedly major innovations in their own right, two additional aspects of their diffusion should be noted. First, automation technologies have been introduced largely on a stand-alone basis, advancing the level of intra-activity automation within the firm but not involving any linkage either within the same sphere or across spheres. Much of the multi-billion dollar investment in automation made by the U.S. auto transnational corporations (TNCs) in the early 1980s, for example, was in stand-alone equipment. The bias towards installing islands of automation was typical of much of the engineering sector and manufacturing industry through the 1980s and is a pattern that will continue as the range of applications expands, functions increase, and relative unit costs decline.[19/]

1.21 Second, and more important, the focus of innovation and investment has shifted increasingly toward the intra-sphere and inter-sphere integration of these islands of automation. The emphasis now is on capturing systemic gains through exploiting the flexibility inherent in the technology. Flexible automation's implications for firm-level gains and international competitiveness are qualitatively different from the issues raised by stand-along automation.[20/] This evolution toward more flexible, integrated systems is feasible because automation technologies share a common knowledge in the use, process-

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17/ One U.S. producer of PC-based CAD systems sold more than 100,000 low-cost terminals in 1986.

18/ See Jacobson, Steffan and Charles Edquist (1988), Flexible Automation: The Global Diffusion of New Technology in the Engineering Industry, Oxford: Basil Blackwell Ltd, for the most comprehensive diffusion review available on stand-alone automation techniques.

19/ This wave of stand-alone automation has attracted a great deal of attention in the analytical literature -- not only in relation to industrialized countries but also, to a much more limited extent, in implications for developing countries. See the articles in Hoffman (1985) and the references in James (1987).

20/ These recent developments are the subject of most of the current research by policy analysts in the industrialized countries. See, for instance, Haywood and Bessant (1987) and Bessant and Haywood (1987), as well as New (1986), Voss (1986), Boody and Buchanan (1986), and Senkar and Beesley (1987). So far the literature has hardly begun to interpret this new trend from the perspective of developing countries -- an issue to which we return in the Conclusion.

ing and transmitting of information. The way is open now to link together automation technologies within the separate spheres of production, design and coordination and to integrate manufacturing with design, under the coordination of management. This process is being driven by the underlying technological logic of microelectronics that, in principle, the greatest gains from the industrial use of information technology occur when the highest degree of integration is achieved.

1.22 CIM. The generally accepted name for this trend toward full f manufacturing systems is computer-integrated manufacture. The CIM concept, strictly speaking, refers to the ultimate manufacturing installation, where all the relevant activities in a company's operations are brought together under integrated computer control, a development that used to be referred to as the "factory of the future". However, the concept also is used more generally for the many emerging configurations and levels of integrated automation within the factory. Considerable strides are being taken toward ever higher levels of CIM, such as the integration of CAD with computer-directed machining operations (known as CAD/CAM); CAD links into computer-based inventory control and purchasing systems; and the linking of all three (inter-sphere automation) via CIM. These leading edge CIM applications have, naturally enough, attracted a great deal of media attention.[21/]

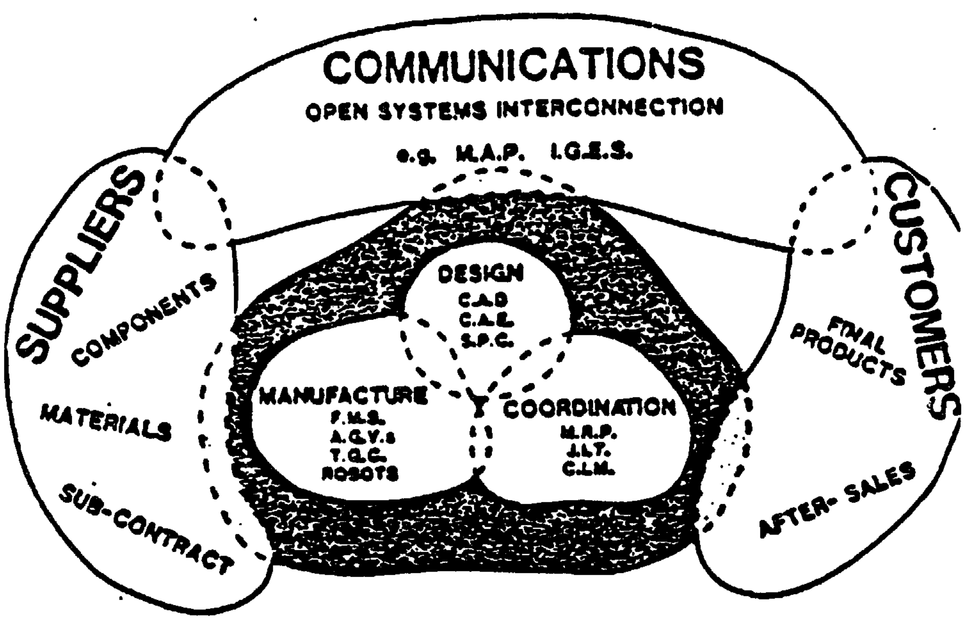
1.23 Moreover, integration has gone beyond the factory and company bounds. Electronic communication has led to the development of a range of computer-based links in design, production scheduling, purchasing, and shipping among suppliers, producers and customers. This level of integration between producers and suppliers is represented in Figure 1.3, with indications of the different forms that intra-firm automation can take.[22/]

21/ The firm-level factory automation landscape exhibits similar characteristics across Japan, Europe and the United States. In each region there is a select group of leading-edge firms, perhaps 30-40 in total, followed by a much larger groups of firms now aggressively following, albeit at a less advanced stage--and benefitting from the lessons of the leaders. Arbose (1985) gives details of the SKF installation in Sweden and the massive GE CIM complexes in Pennsylvania and Kentucky; Handke (1982) and Jelinek and Godhar (1986) discuss the well known CIM facility at Messerschmitt-Bolkow-Blohm in West Germany; Hoffman and Kaplinsky 1988) give details of the extensive CIM setup at FIAT in Italy; and ECE (1986) describes a number of other CIM installations including those at Fujitsu Fanuc and Yamasaki Machinery Works in Japan.

22/ Hoffman and Kaplinsky (1988) describe one of the most advanced examples of computer-based intra and inter-firm automation at Nissan's Murayama plant where computers control all aspects of production, including the operation of flexible automation technologies, production scheduling, components ordering and in-plant JIT. Computer-based ordering accounts for 90% by quantity and 90% by value of all components used.

Figure 1.3

Organization in the "Factory of the Future"?



M.A.P.	Manufacturing Automation Protocol
I.G.E.S.	Initial Graphics Exchange Specification
C.A.D.	Computer-Aided Design
C.A.E.	Computer-Aided Engineering
S.P.C.	Statistical Process Control
F.M.S.	Flexible Manufacturing Systems
A.G.V.	Automatic Guided Vehicles
T.Q.C.	Total Quality Control
M.R.P.	Material Requirements Planning
J.I.T.	Just-in-Time
C.I.M.	Computer-Integrated Manufacturing

Source: Hoffman (1988)

1.24 The trend toward full integration will almost certainly define manufacturing in the long term, but the most immediate and relevant technical changes involve the design and introduction of flexible systems within the manufacturing sphere--particularly intra-sphere automation. In this area the distinctions usually drawn among the three levels of integration are:

- <u>flexible machining units</u> (FMU) which are one-machine units, typically a machining center (combining functions previously carried out by individual CNC tools) equipped with automatic tool-changing and material-loading devices that allow some degree of unattended operation;

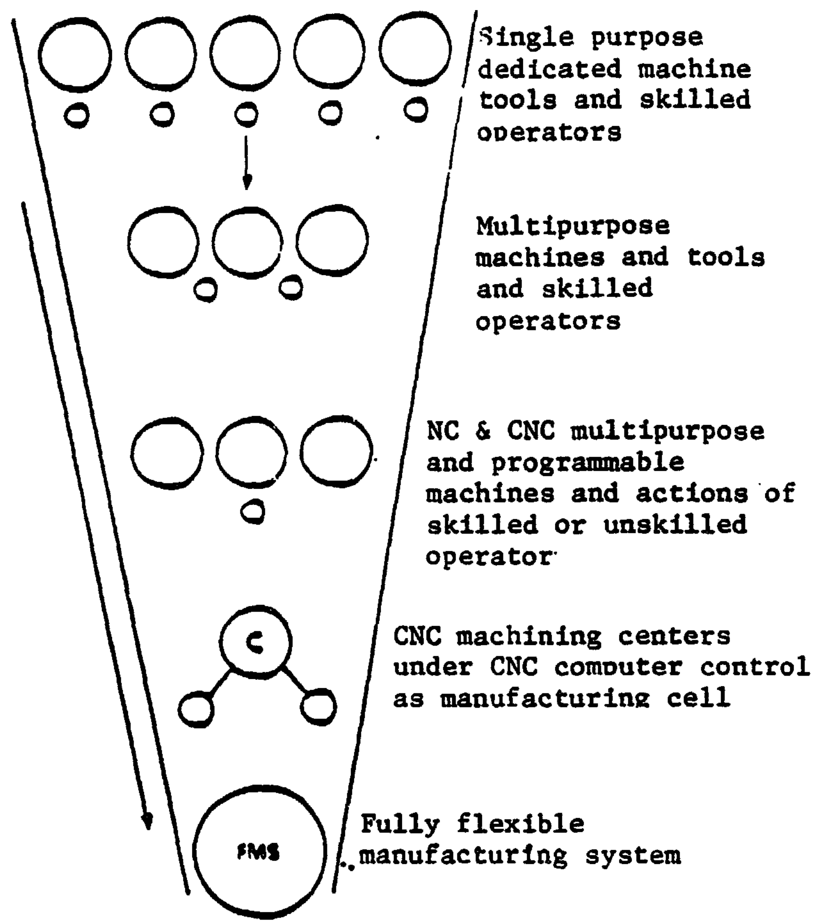
- <u>flexible manufacturing cells</u> (FMC) comprising two or more machines (machining centers and/or individuals CNC tools) plus material handler, all controlled by computer; and

- <u>flexible manufacturing systems</u> (FMS) made up of two or more FMC, some form of automatic transportation system to move pallets, workpieces, and tools between machines, and all controlled by computer.

Figure 1.4 captures these different levels of intra-sphere integration in metalworking.[23/]

<u>23/</u> Within metalworking, developments are proceeding in three directions. First, where most FMS are now used on "prismatic" products, new generations can handle rotational products as well. (Prismatic parts are based on cuboid shapes such as gearboxes, and rotational parts are cylindrical in shape, such as axles and shafts. Currently these are handled separately, with the majority of FMS used for prismatic machining. Future FMS will be able to handle both shapes, thus eliminating a completely separate stage in processing). Similarly, FMS have been developed that can handle sheet metal work whereas previously they had been confined to activities involving metal cutting of one form or another.

Figure 1.4 The Trend towards Integration in Metalworking



Source: Bessant and Rush (1987)

1.25 Technological developments in this area are multi-dimensional, and although diffusion is proceeding at a reasonable pace, flexible manufacturing is still an immature technology. Users and suppliers continue sizeable R&D projects, while considerable research is being supported by the public sector. Despite this degree of experimentation, there is little doubt that the orientation of industrial innovation within engineering and manufacturing has shifted irrevocably in this direction. Three aspects are discernible for future progress:

(i) Increasing flexibility. Changes under way in manufacturing technology represent a truly major advance in flexibility and are responding to several factors: increased international competition, combined with a change in the nature of market demand for greater quality, more variety, custom product specification, improved delivery times, and a shorter product life cycle; factory automation suppliers offering flexibility and higher integration at lower cost--a trend that will continue as output levels increase and standardization prevails;[24/] and most important, the sizeable competitive advantages offered by the enhanced flexibility of integrated systems, advantages that enable firms to meet changing market demands without sacrificing scale economies.[25/]

1.26 This new concept of flexibility has a number of dimensions, providing technological advantages not available previously:

- product flexibility--for easier changeover from product to product;
- volume flexibility--for efficiently accommodating changes in volume;
- routing flexibility--to process parts via different routes within the plant in response to breakdowns or other factors;
- machine flexibility--to make different parts within a product family;
- operation flexibility--to vary the sequence of operations; and
- process flexibility--to produce a product family in different ways using different materials.

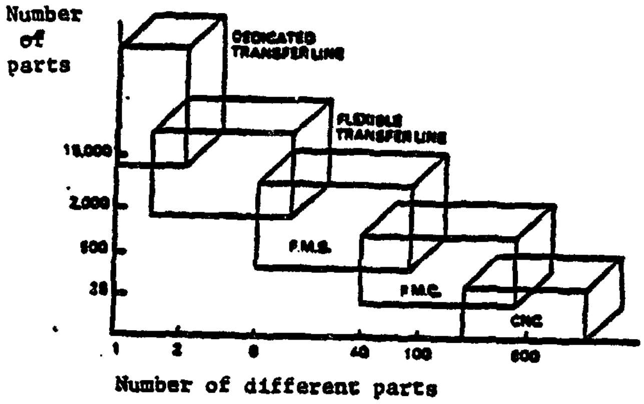
24/ Haywood and Bessant (1986) show that the average cost of FMS installed in the U.K. has declined from US$8 million in the early 1980s to US$1.5 million in 1986; costs for FMU and FMC have also declined considerably.

25/ This shift in manager's perspective towards flexibility as a source of economic gains in production is precisely the kind of change in the collective "common sense" that one would expect to see as evidence of the diffusion of the new technological and organizational paradigm. See Perez (1985) and Piore and Sabel (1984).

Increased flexibility thus yields benefits in reducing lead time, increasing capacity utilization and throughput rates, expanding product variety, and lowering labor requirements.

1.27 (ii) Proliferation of options. Depending on how the different elements of the technology are combined, numerous techniques encompassed by a flexible manufacturing system (FMS) are now available for each area of manufacturing (see Figure 1.5). These include different types of FMU and FMC and also techniques for storage, handling, machine feeding, tooling, and the control system. Concerning FMS, most systems still are put together on a one-off basis. However, the technology is sufficiently advanced to allow configurations that cover a much wider variety of part/volume combinations, which means that firms of all sizes are able to use FMS; most previous users were large TNCs.

Figure 1.5 Options in Flexible Manufacturing Systems



Source: Bessant and Rush (1986)

1.28 (iii) Extension of the scope of applications. The third characteristic of current and likely future trends is the penetration of flexible automation into a widening range of sectors, products, and manufacturing activities. Users of flexible manufacturing technologies in the late 1970s and early 1980s tended to be in select segments of the engineering industry, such as aerospace, vehicles, and agricultural machinery, where FMS were used primarily on a narrow range of operations on particular types of components. In metalworking, assembly FMS are now in operation in Italy, the U.S., and Japan, thus bringing FMS into operation in the largest area of production activity. Data indicate that over 60% of all production activities within engineering involve assembly amenable to flexible automation.[26/]

26/ Bessant (1986).

1.29 These developments are rapidly expanding the range of engineering sector activities where FMS can be applied, but the process of FMS diffusion will not be confined to engineering--the philosophy of flexible manufacturing is relevant to all batch-based industries. Increased flexibility and integration mean that the scale-related constraints that have operated in batch and mass production are easing substantially. Minimum scale economies for mass production at the plant and product level are dropping, and batch producers are able to achieve scale economies at much lower output levels.[27/] Hence, a new group of users of flexible manufacturing technology is now emerging in consumer appliances, plastics, forging, glass, electric motors, pumps, marine components, valves, hand tools, switch gear, and even garments and shoes.

FMS: Impact, Diffusion, Investment

1.30 Evidence on the diffusion of FMS and on the gains arising from their introduction is mounting rapidly. Some of the evidence is presented here in table form. Table 1.4 shows results from some of the first large FMS installed in the U.S.[28/] Even at this early stage, the pattern of systemic gains in labor productivity, reduction in cycle time, and product flexibility was established. Table 1.5 gives a partial summary of the more recent (1986) UN Economic Commission for Europe (ECE) survey of more than 100 FMS throughout the world. Tables 1.6 and 1.7 provide a comparison between old and new systems installed by U.S. and Japanese auto component firms who are planning to introduce another 15 to 20 FMS lines soon.[29/]

27/ See Kaplinsky (1986) and Hoffman and Kaplinsky (1987) for an extensive discussion of the impact of flexibility on scale economies in batch production. See Bessant (1986) for a discussion of FMS in other sectors, and Hoffman and Rush (1988) for a study of FMS and other automation technologies in the clothing sector. A recent dramatic example of the reduction in scale economies attainable via flexible automation comes from Nissan U.K.'s new engine plant where it will be economically viable to produce 80,000 engines per year, as opposed to the previous break-even point of 300,000 units annually for an in-house engine plant. See the Economist (1988).

28/ Ayres and Miller (1984) were among the first to review FMS experience in the late 1970s.

29/ Hoffman and Kaplinsky (1988).

Table 1.4 Capital Costs and Reported Savings in Operating Costs for Selected U.S. Flexible Manufacturing Systems Installed before 1982

User Sector	Cost (US$, 1982)	Product volume and part variety	Comparisons with old system
Truck axles	$5.6 million	24,000* 45**	1/4 floor space; set-up costs eliminated
Aircraft engines	$8.4 million	24,000* 9**	1/3 floor space; 1/4 labor; 50% number of part-holding devices
Tractor components	$18.0 million	50,000* 8-13**	Cost: $18 million to replace dedicated transfer line at cost of $28 million
Truck components	$5.0 million	65,000* 5**	Cost of FMS the same as dedicated transfer line, with comparable cycle time but less flexibility
Construction equipment	$5.0 million	8,0000* 8**	Total transit time through system: old: 8.5 hours; new: 0.3 hour

* Total number of parts per year machined on system
** Number of different part types machined on system

Source: adapted from Ayres and Miller (1984)

Table 1.5: SUMMARY OF SELECTED RESULTS FROM ECE SURVEY OF FMS IN EUROPE

- For a subset of 39 installations, 21 have reduced operator numbers between 50% and 75%, and in 10 installations the number of workers has been reduced by more than 75% over conventional lines.
- In 28 installations, 19 have reduced the number of machine tools by more than 50% compared to conventional lines.
- In 18 installations, all have reduced lead time by more than 25%; of 31 additional installations, eight have reduced lead time by between 50% and 75%, and another 18 have reduced lead time by more than 75%

Source: Adapted from ECE (1986), Appendix 1

Table 1.6 FMS Installed by Japanese and U.S. Auto Components Firms

Japanese FMS

Firm A - FMS for brake assembly at 40,000 units per month

	Old line	FMS
Capital costs	3 x Y30m (1)	Y120m (2)
Workers (3)	12	1
Tooling	Same in both lines	
Energy	Same in both lines	
Space		1/3
Number of product types	6	20 (4)

Notes: (1) FMS output equivalent to three old lines
(2) Plus development costs associated with team of four or five people working four to five years
(3) Requires significant increase in maintenance personnel and capabilities
(4) Parts recognized by "touch"

Firm B - FMS for assembly of speedometers

	Old line	FMS
Number of lines (1)	3	1
Number of product types (2)	2-3	50
Workers (3)	30+	3
Capital costs	Y100m	Y300m

Notes: (1) FMS output equivalent to three old lines
(2) Adjustment from one model to another is triggered by dummy part inserted into line
(3) No extra maintenance personnel required

Source: interviews

Table 1.7 FMS Installed by Three U.S. Components Firms

	Firm A Old line	Firm A FMS	Firm B Old line	Firm B FMS	Firm C Old line	Firm C FMS
Product	Compressor		Air conditioner and compressor		Brakeshoes	
Number of lines	4	1	3	1	2	1
Capital costs	$2.5m	$12m	$300 $800,000 each	$8-10m		$2m
Workers	24	4	16	2	5 per line	1
Space				50% reduction		
Number of product types	1 per line	10		86 different parts	2	6
Output		75% increase		30% increase		46% increas
Comment		35 manyears of software R&D required				

Source: interviews

1.31 Finally, Table 1.8 gives details of the most recent survey of FMS carried out in the U.K.[30/] and highlights important trends. First, it confirms the systemic gains described above: lead times reduced on average by 74% work in progress (WIP) by 68%, stock turnover improved by 3 to 4 times, and machine utilization up from 50% for stand-alone CNC tools to 80% on average for the systems listed. The table reveals shifts in FMS parameters, indicating what is ahead and confirming the general trends. The average cost of the systems has declined from US$8-$15 million to US$4 million, with 72% of the systems in the sample costing less. Batch sizes are being reduced dramatically, with 58% of the sample handling batches of 10 or fewer units. Before they could cope only with small-parts families; now 22% of the sample can handle more than 100 different parts. Finally, the size of user firms is dropping, with 69% of the sample FMS in companies with fewer than 1,000 employees.

Table 1.8 Summary of Gains from FMS Used by 50 U.K. Engineering Firms, 1986

Lead time reduction	74%
Work-in-progress inventory reduction	68%
Increase in machine use	63%
Turnover improvement	3.5 fold

Source: Bessant and Haywood(1986)

1.32 Trends in investment and distribution. The few reliable studies on the pattern of FMS investment document a rising rate of diffusion across a growing range of sectors and users. The ECE in 1986 estimated world stock of FMUs to be in the region of tens of thousands and the total stock of FMCs around several thousands.[31/] Estimates for the stock of installed FMS vary widely.[32/] One estimate indicates about 1,000 now installed, with an expected annual rate of growth of over 20%.[33/]

30/ Bessant and Haywood (1986).

31/ Only fragmentary evidence on the rate of growth is available; the stock of the U.S. installed machining centers (key components of all flexible systems) grew from 17,000 in 1978 to 24,000 in 1983.

32/ ECE (1986).

33/ Bessant and Rush (1987).

1.33 Expectations are that the shift to flexible manufacturing will increase significantly over the next ten years, with the share of systems investment as part of investment in total factory automation rising considerably. Estimates of total investment in automation vary from $32.3 billion to $200-300 billion by 1990--with $100 billion expected to be spent in the U.S. alone.[34/] Table 1.9, drawn from the lower estimate, shows how the amount spent for systemic elements such as factory computers and programmable controllers, already quite high by 1985, is expected to increase substantially by 1990.[35/] Obviously, country-specific patterns of future investment in factory automation will vary in size and in configuration, with the U.S. and Japan expected to be the leaders (Table 1.10).

Table 1.9 Estimated Allocation of Investments in Factory Automation (US$ millions)

	1985	1990	1995
Factory computers and software	935	2500	6500
Materials handling systems	2000	4500	8000
Machine tools and controls	3000	4800	7000
Programmable controllers	50	550	3000
Robots and sensors	65	660	2800
Automatic transfer and equipment	800	2000	4000
Total spending on automation	$6850	$15010	$31300

Source: Dataquest, cited in Port (1986)

34/ See ECE (1986) for a comprehensive review, and The Economist (1987); Saporito (1987); Port (1986); and Arbose (1985) for different numbers relating to the future. The Economist quotes Hewlett-Packard executives saying "that 96,000 factories in the United States are currently in the process of installing CIM in one form or another. In a year or two, many of them will become global forces to be reckoned with; some will no doubt conquer the foreign competition and become the new market leaders." Arbose (1985) quotes a vice president at ADL Ltd. who estimates that "between 50% or 60% of the manufacturing companies in Europe, the U.S. and Japan have made some progress (towards integration) by adopting CAD, MRP (Manufacturing Resource Planning), robots and FMS. The remaining firms have little hope of being internationally competitive in the 1990s."

35/ Arbose (1985) cites an A.D. Little study that predicts 50% of a company's in-house computing power will be devoted to manufacturing and engineering by 1990, compared to 25% today.

Table 1.10 Number of Fully Integrated Flexible Manufacturing Systems Estimated to be in Use by 1990

Japan	320
USA	150
West Germany	70
France	45
UK	35
Italy	30]

Source: The Economist (1987)

1.34 Despite the buoyant optimism underlying these estimates, when the technological future will arrive in entirety is unpredictable. The integration of different elements of automation technology--particularly across different spheres of activity--is in fact technically extremely complex. Similarly, as discussed below, FMS are difficult systems to operate, requiring sophisticated supporting services and highly trained workers. Both these factors will inevitably retard the diffusion process and limit the cost-effective use of FMS to firms exhibiting a specific set of product characteristics, total output, and scale of production runs. Thus, large numbers of small and intermediate firms that, in principle, should be able to benefit, will in practice find the use of full-fledged FMS an unviable proposition for a considerable period.

Lessons from the Diffusion Process: the Importance of Organizational Compatibility

1.35 As the last set of comments indicates, although a fundamental technological transformation is underway in engineering, it is proving to be a slow and painful process at the firm level. Case studies on the introduction of advanced manufacturing technology indicate significant problems. In many cases, returns on the investment have been much lower than hoped for, and the learning period has been protracted and difficult. For example, a study by the British Institute of Management revealed that of 64 firms with FMS, more than two-thirds had achieved only a "low payback." A larger survey of 250 firms showed a similar pattern of unfulfilled expectations in connection with a variety of automation technologies. A number of analysts [36/] report problems with the introduction of complex integrated systems in the European engineering industry and highlight the growing caution among potential users that already has caused substantial downward revisions of investment plans.

36/ Bessant (1986), Senker and Beesley (1986), Boddy and Buchanan (1985), and Blumberg and Gerwin (1984).

1.36 Parallel stories of problems and disenchantment with advanced systems also have surfaced in the U.S. The massive wave of investment in automation from 1980 to 1986 was carried out in full expectation that a "technological fix" was the key to restoring competitiveness, particularly against the Japanese. The stand-alone automati n introduced over this period was assimilated relatively easily, yet virtually all the firms that pursued larger, more ambitious automation projects experienced unexpected difficulties. Projects written up in glowing terms in the mid-1980s have since been revealed to have been fraught with problems.[37/]

1.37 The best known case of technological snafu involves U.S. auto industry attempts to repel the Japanese invasion of their markets by relying on the massed technological battalions of factory automation. General Motors (GM) led this charge with a US$40 billion investment plan that included US$5 billion for fully automated production of the Saturn car, US$20 billion to automate old factories and build new ones, and the rest for a variety of expensive high-technology projects. The advantages gained were meant to allow GM to compete head-on against the Japanese (and Ford and Chrysler) and to re-establish its pre-eminent position.

1.38 Instead, the company encountered nightmarish and costly complications, particularly in showcase projects.[38/] Consequently, eight years and US$40 billion later, it is not the Japanese, nor Ford or Chrysler, but GM that is in trouble. Its market share has declined from 48% in 1977 to below 36% in 1987, when it also plummeted to last place in productivity and profits. The company faces the real possibility of having to shut down hundreds of thousands of additional units of capacity by 1990 because it cannot match standards of productivity and quality now being set by Japanese-owned but U.S.-staffed plants in the U.S.[39/]

1.39 <u>The need for organizational compatibility</u>. Explanations by analysts of what has gone wrong with the introduction of advanced manufactur-

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<u>37/</u> The Economist (1987) comments on many of these, while Port (1987) and Whitney (1986) discuss other aspects.

<u>38/</u> Despite the $500 million spent to equip its Hamtranck Cadillac plant with the largest army of robots and computers in any auto plant anywhere, that plant is still nowhere near the quality and productivity of GM's NUMMI joint venture with Toyota in Fremont, California, where automation is limited but where Toyota-style management and organizational practices are in place. Similarly, although $400 million was spent on refurbishing Buick City with flexible tooling, the plant has had one of the slowest startups in history and is still plagued with problems. And finally, there are serious questions being raised about whether the Saturn project will ever get off the ground. See the Economist (1987) and Business Week (1987) for media reports, and Hoffman and Kaplinsky (1988) for an analysis of GM's problems.

<u>39/</u> Womack (1987).

ing technology are illuminating. Western companies' high-tech indigestion frequently resulted because the absorptive capacity of the company, plant, and workforce was overwhelmed. Another aspect is that these highly automated plants were, in fact, over-automated. A variety of technical problems, particularly in interface software and network communications, proved difficult to solve at first, although these problems are being overcome through a forced learning process--as shown by the success of smaller-scale FMS efforts that followed the first round of projects.[40/]

1.40 Besides technological overkill, two other sets of factors were found to play major roles in absorption problems. Most fundamentally, introducing sophisticated integrated manufacturing systems into plants that operate inefficiently does not eliminate the original problems and often makes them worse. In the words of one U.K. manager, "all you get when you put a computer into a chaotic factory is computerized chaos."[41/] Thus, automating existing activities without giving careful thought as to how these might be rationalized and simplified was found to be a recipe for disaster.[42/]

1.41 Detailed research on these problems has shown that the key to success does not lie in technological wizardry but in planning and preparation. Successful firms first set out to learn how their factories function and, operating on the principle that complexity is the root of all evil, then simplified all procedures and tasks, eliminating everything that did not contribute to value. This eliminated many steps in the manufacturing process, including tasks that initially seemed candidates for automation.[43/] Within this approach, automation takes place incrementally, which is less costly and much easier to absorb. Such rationalization in fact can do away with the need for highly integrated systems such as FMS.[44/]

1.42 The second set of factors for successful implementation of flexible manufacturing technology involves achieving compatibility between the technology and the organization into which it is being introduced. The scope and depth of the organizational accommodation required in advanced manufacturing systems differ substantially from that previously encountered in stand-

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40/ See The Economist (1987) for a discussion.

41/ Bessant and Rush (1987).

42/ This is borne out by the successful cases of advanced manufacturing computerization involving companies such as Allen-Bradley, John Deere, Caterpillar, Hewlett-Packard and many others. See Cook (1986), Feder (1987) and The Economist (1987) for examples.

43/ Schonberger (1986) carries a number of examples of this process, including that of one engineering company, which after spending millions installing a computerized inventory and production monitoring system, found that it was no longer necessary once the company simplified its production process.

44/ Schonberger (1986) and Bessant and Rush (1987).

alone technology and go far beyond the need to simplify procedures. In effect, an entirely new way of thinking about the management and organization of production becomes necessary when firms move into integrated flexible automation.[45/]

1.43 Two types of adaptation are particularly important:[46/]

(a) Functional integration, which implies minimizing of inter-departmental and skill-based boundaries to reflect the integrated nature of the technology. Such integration is necessary at all levels but is particularly important in two area: First, to bring the system into use, design and production staff need to work together to develop suitable products. Enormous gains can result from "designing for manufacturability" that would otherwise not occur.[47/] Similarly, in operating the system, new groupings of multi-skilled operators and engineers are needed. These must have close liaison with scheduling and marketing staff to ensure full use of the system's flexibility.[48/] The basic objective of greater functional integration is that specialist skills are not eliminated but are applied in a more coordinated fashion by groups of people thinking in systematic terms about the manufacturing process.

(b) Vertical integration, which is necessary to match the technology's flexibility and rapid response capacity. This implies the creation of a managerial decision-making structure less hierarchical than traditional structures. The aim is to have a management structure that is closer to production but also capable of a much greater degree of delegated autonomy. The technology's flexibility allows those with the most knowledge of the system and its capabilities to make decisions in response to rapidly changing market conditions. This also implies that engineering, supervisory, and other technical staff move into a supporting role vis-a-vis production groups.

45/ Dempsey (1982).

46/ Bessant and Rush (1987).

47/ The concept of "design for manufacture" is, perhaps, the latest term to emerge from the study of Japanese organizational practices. Simply stated, the idea is that products are designed explicitly to simplify the manufacturing process. This approach makes eminent common sense but was ignored by western firms until recently. The improvements recorded are impressive--number of parts per product are reduced by 40%, 50% and even 80%, greatly simplifying the subsequent production process. See Schonberger (1987) for numerous examples.

48/ See Jones and Scott (1987) for an excellent case study on these issues, as well as Handke (1982), Brodner (1985), and Wall (1986).

1.44 A great deal of experimentation is going on within technology user firms on the best way to simplify procedures and achieve functional and vertical integration. (Many of these issues are discussed in Chapter III.) There is impressive evidence that organizational adaptation can have a profound impact on manufacturing performance wherever new technology exists. Most recent studies include strong arguments about the critical need for organizational adaptation before flexible manufacturing systems are introduced.[49/] For instance, studies on the U.S. automobile industry recognize that the organizational changes by Chrysler and Ford--patterned closely on Japanese practices--as part of their multibillion dollar automation efforts have been critically important in allowing Chrysler and Ford to sweep past GM in productivity and profitability.[50/]

1.45 Unfortunately for all three of the U.S. firms, they still lag far behind the best-practice standards set by Honda and its North American operations. Honda's first U.S. assembly plant (1982) relied on fixed automation and Japanese-style organization to gain a significant share of the U.S. market. Building on this, the company has embarked on a massive flexible automation scheme that will remove two-thirds of all labor input in machining and assembly by the early 1990s.[51/]

1.46 Japanese superiority in flexible automation now dominates the engineering sector--despite the common and mistaken assumption that the West, particularly the U.S., is ahead in full CIM installations and is, therefore,

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49/ See references given in footnote 18 as well as Senker and Arnold (1983); Fleck (1985); and Waterlow and Monniot (1986).

50/ See Altshuler, et al. (1984); Hoffman and Kaplinsky (1988); and the discussion in the next chapter.

51/ By this time, Honda will have a total capacity of 500,000 units, a world scale engine facility, and a number of affiliated component plants bringing local capacity to 75% for an investment of 1.7 billion. The major advances Honda is making into the world of flexible automation are typical of Japanese auto and other engineering firms. The key factor is that Japanese firms, by and large, already have an organizational structure suited to flexible automation. They have already won the battles western firms are just beginning to fight in this area. This gives them an enormous jump over western firms, even though many of the latter, particularly in the U.S., invested earlier and more heavily in automation technology. The evidence presented in Jaikumar (1987) attests to this. See also Womack (1987) and Hoffman and Kaplinsky (1988). The combination of organizational efficiency and flexible manufacturing that Honda has established is so powerful that, in the words of a noted auto analyst, "the demonstration effect of this facility on American industry in general and the auto industry in particular is hard to overestimate...Senior executives, plant managers and union leaders in American companies...[have] a simple imperative: match Honda's achievements in productivity, quality, and factory flexibility in the United States by the early 1990s or be prepared for bankruptcy." Womack (1987).

leading the technology race. In fact, since 1980 Japan has invested in flexible systems at a much higher rate than other industrial nations--by more than two-to-one compared to the U.S. Its factories boast over 40% of the world stock in flexible tools--with small to medium producers using two-thirds of them. The crucial lesson from this situation is that Japanese leadership in flexible technology has emerged not because of greater investment but through more efficient technology use.

1.47 Stunning confirmation of this assessment comes from a comparative study of the performance of 95 FMS in use in the engineering sector in the U.S. and Japan. Comparison of U.S. and Japanese FMS performance are given in Tables 1.11 and 1.12.

Table 1.11: PERFORMANCE COMPARISON OF FMS IN THE U.S. AND JAPAN

	U.S.	Japan
Systems development time (years)	2.5 to 3	1.25 to 1.75
Number of machines per system	7	6
Types of parts produced per system	10	90
Annual volumes per part	1,727	258
Number of parts produced per day	88	129
Number of new parts introduced per year	1	25
Number of systems with unattended operations	0	1
Utilization rate over two shifts	52%	64%
Average metal cutting time per day (hours)	6.3	20

Source: Jaikumar (1987)

Table 1.12: MANPOWER REQUIREMENTS FOR METALCUTTING OPERATIONS TO MAKE SAME NUMBER OF PARTS ON U.S. AND JAPANESE FMS

	Conventional System		FMS
	U.S.	Japan	Japan
Engineering	34	18	16
Manufacturing overhead	64	22	5
Fabrication	52	28	6
Assembly	44	32	16
Total number of workers	194	100	43

Source: Jaikumar (1987)

1.48 The reasons for the differences lie in the design and operation of the systems. U.S. managers approach their tasks with the perception that the FMS is simply another set of machines for high-value standardized production. They are still operating in terms of mass production and "old-fashioned Taylorism and its principles of scientific management." (See footnote 79 in Chapter II for an explanation of Taylorism.) As a result, U.S. firms pursue precisely the wrong objectives: design is separated from execution; skilled machinists are replaced by narrowly trained operators; output and uptime are valued more than flexibility and process improvement.52/ Such firms attempt "narrow-purpose production on expensive FMS technology designed for high-powered, flexible usage."53/

1.49 The Japanese, however, have grasped fully the potential of the technology. They have built on their already highly flexible production organization, to develop the management structure and practices necessary to extract the full benefit of flexible automation. Maximum flexibility and reliability are designed into the system; small groups of systems engineers design and run-in the installations, thereby capturing learning benefits that feed directly into the design of the next version. Responsibility for operation and innovation now falls to small teams of highly skilled, multi-function engineers, while senior management, relieved of daily production concerns that typically preoccupy their counterparts in the West, can concentrate on planning for changes in market demand. These changes, particularly the engineering bias (engineers now outnumber production workers by 9 to 1), "signal a fundamental change in the environment of manufacturing. In the FMS environment, engineering innovation and engineering productivity hold the keys to success."54/

1.50 For U.S. and European engineering firms, the implications of these findings roughly parallel the situation in motor vehicles--the choice is to match Japanese standards for FMS performance or fall further behind. They must learn and apply lessons from the Japanese design and management of flexible systems, and they must become aware of the implications of the

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52/ Jaikumar's conclusions on this are blunt: "A close look at how U.S. managers are actually using (FMS) technologies (shows) ... they are buying the hardware of flexible automation -- but they are using it very poorly. With few exceptions, the FMS installed in the U.S. show an astonishing lack of flexibility. In many cases they perform worse than the conventional technology they replace. U.S. companies use FMS the wrong way. Compared with Japanese systems, those in the U.S. produce an order-of-magnitude less parts. They cannot run untended, are not integrated with the rest of their factories, and are less reliable. Even the good ones form, at best, a small oasis in a desert of mediocrity. Rather than narrowing the competitive gap with Japan, the technology of automation is widening it further. The technology itself is not to blame; it is management that makes the difference." Jaikumar (1987).

53/ Jaikumar (1987), p. 71.

54/ Jaikumar.

increased engineering intensity of production. Whether the response from U.S. engineering firms and auto makers will be soon enough and sufficiently broad to head off further Japanese advances remains to be seen.[55/]

1.51 However, two sets of conclusions emerge. First, the conventional fixed automation technology of mass production and the Taylorist principles of scientific management are becoming less and less relevant. With the minimum efficient scale for flexible manufacturing now on the order of six machines--and with fewer people--size and scale no longer are overwhelming barriers to market entry nor guarantees of competitive advantage. Managerial competence and understanding of the systemic and strategic implications of flexibility are the new determinants of market success. National capabilities in these areas will determine the international distribution of benefits from the technological transformation. The continued dominance of the U.S. and Europe as the leading users and suppliers of engineering technology is not guaranteed. This portends a shift in the structure of the global system of production and exchange in engineering, which is perhaps even more important than the underlying technological transformation.

1.52 The second set of conclusions bears directly on the focus of the rest of this paper says. The diffusion of flexible manufacturing technology is still in the very early stages. However, it is significant that management issues and organizational factors already are proving to be key determinants of successful adoption and diffusion of the new technology--and hence are influencing international competition and division of labor. Analysts concerned with the implications of radical technical change for developing countries have not yet understood the primacy of organizational over technical factors in this regard since many of these observes have been even more guilty of embracing the myth of technological determinism than have Western plant managers.

1.53 Even more important are the consistent findings that the majority of benefits from technology use come not from the technology itself but from rationalization of procedures and organizational change. This indicates that organizational change (and its benefits) are, in fact, separable from technological change. From the perspective of developing countries, this is a factor of considerable importance. For those countries already operating in international markets, the shift toward flexible automation as the dominant production technique appears to imply both an intensifying of competition and a considerable leap over the technological barriers to entry.

55/ Port (1987) recounts a number of cases where technological and organizational changes are being introduced together, for example, in the giant PPG Industries, which is designing and building a $30 million, highly automated glass plant expected to be 50% more productive than any other plant in the world -- and in which Japanese-style management and organizational practices will be in place from the beginning.

1.54 However, the emergence of these new organizational innovations may lead to productivity and performance improvement that are immediately within the grasp of these countries. Equally significant, although trends in flexible automation are important to engineering firms in some advanced developing countries, the new approaches to production organization may in fact be applicable across a broader array of sectors and countries. This possibility raises many questions about the origin, nature, and characteristics of the new organizational practices and their applicability in developing countries, which are issues treated in the next two chapters.

[D-276(a)]

CHAPTER II

ORGANIZATIONAL INNOVATION IN THE ENGINEERING SECTOR

The Erosion of Western Competitiveness

2.01 Although a common topic of discussion today, the competitive woes of Western industry only began to surface in the late 1970s, in the form of dramatic alterations in international trade and economic relations among industrialized countries. The U.S. economy, which had enjoyed global industrial supremacy in the post-World War II era, experienced the greatest change as its share of world trade declined and its trade balances plummeted. As shown by Table 2.1 and Figure 2.1, this reversal in Western, particularly U.S., economic fortunes coincided with the rise of Japan as a formidable international competitor.

Table 2.1 Trade Balance in Manufacturing (US$ billions)

Year	U.S.	Japan	West Germany
1980	18.8	93.7	63.1
1981	11.8	115.6	61.7
1982	-4.3	104.0	67.5
1983	-31.0	110.3	58.7
1984	-87.4	127.9	60.5
1985	-107.5	107.7	59.5

Source: National Research Council (1986) p. 14

2.02 In the late 1970s, Japanese exports established such a powerful presence in specific segments of Western markets that embattled Western producers regarded Japan as the main threat to their market share, as powerfully demonstrated by the experience of the U.S. motor vehicles industry. Whereas early in the 1970s, as Table 2.2 shows, foreign penetration into the U.S. market was extremely limited, imported Japanese automobiles captured 20% of the U.S. domestic market in only eight years.[56]

56/ These early gains in U.S. domestic market share by Japan marked the beginning of a profound transformation in the U.S. auto industry -- virtually forced upon it by the real possibility of having to cede the majority of market share to Japanese producers. Even though substantial changes have occurred in both the technological and organization practices of the domestic producers, U.S. industry is still being pummelled by the superior efficiency and products of the Japanese auto makers. The Japanese could land a car in the U.S. in 1980 at a cost that was US$2,000 less than it cost U.S. firms to build a similar car at home. (The gap has closed somewhat but still remains sizeable.) The net result of a decade of this onslaught was a U.S. auto trade deficit with Japan of US$60 billion in 1986, a growing number of Japanese-owned plants in the U.S. capable of producing in excess of 2 million units, and a massive overcapacity problem that could force the U.S. industry to close down 600,000 to 700,000 units of capacity by the early 1990s.

Table 2.2 Import Share of the U.S, Western Europe, and Japanese Auto Markets

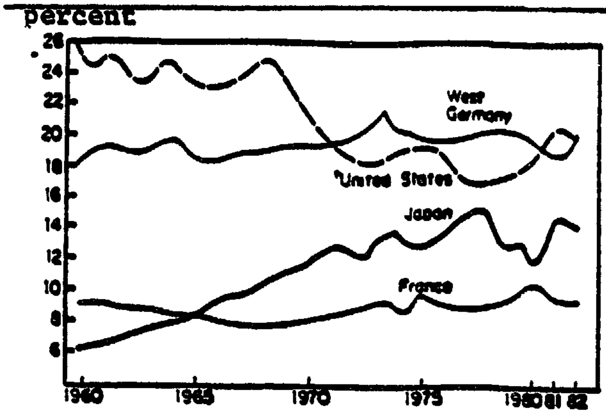
Imports to:	U.S.			Europe	Japan
Exports from:	Europe	Japan	World	Japan	Rest of world
1962	4.8	0.1	4.9	n.d.	1.4
1968	8.9	1.6	10.5	0.6	0.5
1969	8.7	2.5	11.2	n.d.	0.4
1970	10.5	4.2	14.7	1.1	0.5
1971	9.0	5.9	14.9	1.6	0.5
1972	7.6	5.7	13.3	2.7	0.6
1973	9.0	6.2	15.2	3.6	0.8
1974	9.0	6.7	15.7	4.0	1.1
1975	8.9	9.3	18.2	5.2	1.1
1976	5.6	9.2	14.8	5.6	1.0
1977	6.3	12.0	18.2	6.2	1.0
1978	5.9	11.9	17.8	6.3	1.2
1979	5.6	17.0	22.6	7.2	1.3
1980	5.4	22.8	28.2	9.8	1.0
1981	5.8	23.0	28.8	9.1	0.7
1982	5.4	23.2	28.6	8.6	0.7
1983	6.3	19.7	26.0	9.9	n.d.
1984	5.2	18.3	23.5	10.1	1.62
1985	5.6	20.1	25.7	10.7	2.17
1986	n.d.	n.d.	28.3	n.d.	n.d.

Source: Hoffman and Kaplinsky (1988)

2.03 Motor vehicles was not the only product group in which Japan began to amass a sizeable trade surplus at the expense of the U.S. (as well as the U.K., Canada, and France). The same rapid growth took place in medium-technology sectors such as machine tools, railroad equipment, construction equipment, and agricultural machinery. Japanese growth was rapid in high-technology sectors such as consumer electronics and electronic components, as well as in the "sunset" industries, as shown by Figure 2.2.[57/] This emergence of Japan in the early 1980s, both as a threat to Western domestic markets and as a serious challenger for world industrial leadership, set the backdrop against which the features of the new organizational paradigm began to appear.

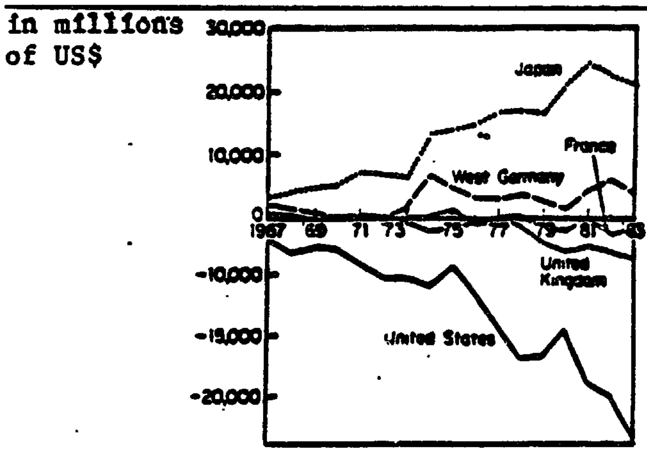
57/ See the analysis in Cohen and Zysman (1987) in Chapter 5; see also NAS (1987) Chapter I.

Figure 2.1 Shares in World Trade in Manufactures for U.S., Japan, France, West Germany 1960-1982



Source: Cohen and Zysman (1987), p. 64

Figure 2.2 Trade Balance for Manufactures, Excluding High Technology Exports, for U.S., Japan, France, U.K. and West Germany, 1967-1983



Source: Cohen and Zysman (1987), p. 74

2.04 The astounding success of Japan in the international economy stimulated a search for explanations for this performance. Early opinion from plant managers, senior executives, and union leaders was that Japanese market share had grown because of unfair advantages gained by dumping and predatory pricing, an undervalued exchange rate, a favorable domestic tax structure and capital markets, and protected Japanese domestic markets -- or at the opposite extreme, because Japanese firms employed much higher levels of automation than Western firms. In short, it was believed that all of these exceptional factors widely favored Japan; if forced to compete on a "level playing field" with the West, Japanese firms would lose their advantage.[58/]

2.05 Detailed studies and extensive visits by U.S. and European managers to Japanese firms in the early 1980s showed that initial Japanese gains in market share derived from the extraordinary advantages the Japanese enjoyed over Western firms in productivity and product quality.[59/] This superiority was not because of illegal actions or advanced automation but because Japanese producers had developed an entirely new approach to production management that differed fundamentally from both the European craft tradition and the U.S. mass production model.

2.06 In principle, these differences revolved around the following aspects:

- Cooperation rather than confrontation between management and workers and between users and suppliers;
- Pervasive concern for quality in all aspects of design and production instead of the singleminded pursuit of cost reduction and volume;
- Flexibility in product mix, output levels, and deployment of labor instead of specialization, strict demarcation, and economies of scale;
- Production according to order rather than to stock;
- Group effort rather than management focus on output (from hostile individuals).

Responsibility for quality control, maintenance, materials ordering, and continuous improvement of every task devolved to work groups while supervisors, technicians, and engineers became support staff.

58/ In America, this reasoning was used by the auto industry to lobby for the severely protectionist Voluntary Export Restraint Programme, designed to limit further erosion of the market until U.S. firms could respond to the threat. See Hoffman and Kaplinsky (1988).

59/ See Hayes (1981), Hall (1981), Wheelright (1981), Garvin (1983), Schonberger (1982) and Altshuler et al. (1984) for the auto sector.

2.07 Many of these organizational innovations were developed by vehicle assembly firms, led by Toyota. The net impact of their application on competitiveness in the auto industry was staggering.60/ Tables 2.3 and 2.4, and Figure 2.3, present some select performance comparisons (standardized for product and process technology) among Japanese, European, and U.S. car firms.

Table 2.3 Workers per Shift to Produce Similar Vehicles in Japan and in Two European Countries, 1980

	Japan	Europe 1	Europe 2
Daily volume	360	379	308
Direct labor per shift			
Stamping	135	58	39
Metal assembly and body shop		362	221
Paint shop	40	151	82
Trim and final	175	453	301
Total direct labor per shift	350	1024	643
Indirect labor per shift			
Inspectors:			
Body	1	28	31
Paint	2	6	7
Trim	2	12	7
Final and repair	10	37	23
Total inspectors per shift	15	83	68
Material handling and line feed	10	328	113
Other	35	601	174
Total indirect labor per shift	60	1012	355
Total direct and indirect	410	2036	998
Absenteeism	1%	6.1%	5.1%

Source: Hoffman and Kaplinsky (1988)

60/ Studies by Altshuler et al. (1984) and Shingo (1981).

Table 2.4 Performance Comparison for Japanese and U.S. Engine and Vehicle Assembly Plants, 1982-1984

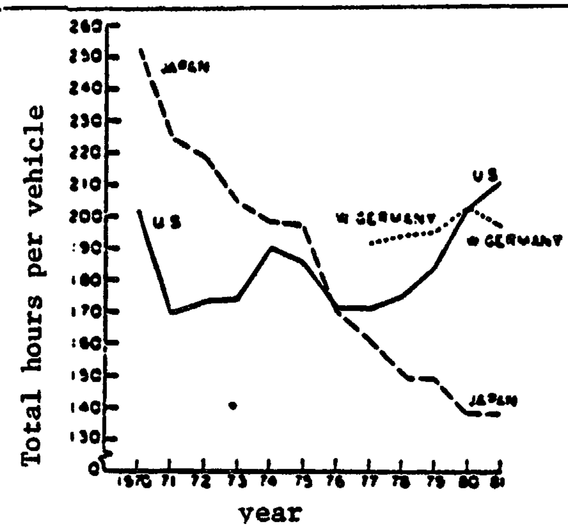
	Toyota Kamigo engine plant	Chrysler Trenton	Ford Dearborn
Products	2.4 ltr/4-cyl 2.0 ltr/4-cyl	2.2 ltr/4-cyl incl turbo	1.6 ltr/4-cyl HO; turbo; EFI
Plant size	310,000 sq. ft	2.2 million sq. ft	2.2 million sq. ft
Hourly employment	180	2,250	1,360
Line rate	1,500/day	3,200/day	1,960/day
Manhours per engine	.96 hour	5.6 hours	5.55 hours
Shifts	2	2	1 assembly 2 machining
Inventory	4-5 hours avg	2.5-5 hours avg	9.3 days avg
Wages	$11.35/hour (excluding fringes)	n.d.*	n.d.*
Robots	none	5	n.d.

	Suzuki Kosai completed 10/83	Mazda Hofu completed 10/82	GMAD Lake Orion completed 12/83
Products	Cultus (Chevy Sprint)	626	Cadillac & Olds C-car
Plant size	553,270 sq. ft	1.5m sq. ft	3.7m sq. ft
Employment	600*	1,800	6,700
Line rate	30/hour 60,000/year	62.5/hour 240,000/year	75/hour 260,000 year
Manhours per car	20**	14***	48.7
Inventory	4 hours avg	30 minutes min. 1 day max.	6 hours avg of high cost items
Wages	$7.40 approx./hours	$10.55/hour	$12.67/hour
Robots	137	155	157

* One shift
** Includes stamping and engine and transmission assembly
*** Includes stamping

Source: Automotive Industries (1985)

Figure 2.3 Total Hours to Produce a Motor Vehicle in the American, Japanese, and West German Motor Vehicle Industries, 1970-1981



Including management and production labor in final assembler and supplier firms

Source: Altshuler et al (1984), p. 160

2.08 As Figure 2.3. shows, Japanese automakers reduced the number of hours required to build a car from 250 in 1970 to 130 by 1981. Table 2.3 shows the huge differences in both direct and indirect staff used by Japanese, European, and U.S. auto firms to produce the same type and volume of vehicle. Table 2.4 shows that differences in plant performance are not due to higher levels of assembly automation, because the number of robots is the same or they are not used at all.

2.09 Although the gap has closed in some areas, in 1987 the best Japanese auto plants using the same number of manufacturing steps could produce a vehicle with 50% of the unit labor input, and only 50% of the defects, of average U.S. and European car plants.[61/]

61/ Womack (1987). Abernathy, Clark and Kantrow (1981), showed Ford and Chevrolet defect rates per vehicles shipped to be 5-6 times that of Toyota in 1979.

2.10 Although the auto industry provides the most widely publicized examples of Japanese manufacturing superiority, studies document that the practices and advantages are present across the whole of the Japanese engineering and manufacturing sector.[62/] A process of organizational innovation leading to continuous productivity and quality improvement has been, in fact, a feature of Japanese industrial management methods since the early 1950s.[63/] There has been a consistent pattern of improvement in quality, productivity, reductions in lead time and work in progress (WIP), and savings in physical space, across many sectors, firms, and product types. Table 2.5 gives a partial selection of organization-based gains in various engineering sector firms. Table 2.6 shows that as a product's complexity grows across sectors so does Japanese efficiency, compared to that of U.S. firms.

2.11 A landmark comparative study of U.S. and Japanese producers of air conditioners showed that the failure rates of products from the best producers (all Japanese) were between 500 and 1,000 times less than those of the lowest quality producers (all U.S. firms).[64/] Air conditioners are standard commodities produced by typical engineering companies in both countries, using mature and unchanging technology in almost identical configurations. It is a product frequently manufactured under license in developing countries. Japanese firms had man-hour productivity levels up to four times greater than U.S. firms. The total costs of quality for the Japanese (including prevention, inspection, and failure costs) were less than half of the failure costs (only) incurred by the best U.S. companies.

2.12 Although the study does not examine the impact of the observed quality differences on international competitiveness, other industries such as consumer electronics, semiconductors, photographic products, and agricultural machinery have learned not to ignore the quality factor when facing competition from the Japanese.[65/]

62/ Clark (1979), Magaziner and Hout (1980), Hayes (1981), Wheelright (1981) and Schonberger (1982).

63/ Deming (1982), Walton (1986), Kobayashi (1986), Shingo (1986), Garvin (1988) and Ishikawa (1985).

64/ Garvin (1983).

65/ In 1980, Hewlett-Packard reported that after testing 300,000 16K RAM chips from 3 U.S. and 3 Japanese manufacturers, the Japanese had a failure rate of zero while the U.S. the rate was between 11% and 19%. The well-documented Japanese inroads into semiconductor markets are easy to explain on the basis of these sorts of figures. Similar stores are told by Magaziner and Reich (1982) and Takamiya (1981) about the demise of the U.S. and European color TV industries. See also Port (1987) and Helm (1987) for other examples.

Table 2.5 Selected Examples of Gains from Organizational Innovation in Japanese Engineering Companies

Product	Time period	Inventory reduction	Lead-time reduction	Space saving	Labor productivity
Precision parts	1973-83	(indexed) 100 - 50	significant ($15m savings via waste elimination)	factor of 3	(indexed) 100 - 250
Stamping/ machining	1977-81	100 - 60	20 days - - 8 days	significant	100 - 178
Auto components	1974-81	100 - 35	significant	significant	100 - 191
Machinery parts		30 - 1	1/2 day -	100 - 50	30% gain
Machining line		100 - 61	days to minutes	100 - 32	from 10 to 4 operators

Source: adapted from Suzaki (1987); Schonberger (1982), and interviews

Table 2.6 The Japanese Edge in Manufacturing

Product	Manufacturing steps	Labor index*
Automobile	1200	1.98
Fork-lift truck	900	1.82
Auto engine	250	1.62
Automatic transmission	200	1.41
Color television	80	1.15
Steel sheet	17	1.00

* Ratio of hours of labor, U.S. vs Japan

Source: Boston Consulting Group, cited in Port (1987), p. 134

The Impact of Organizational Change at the Firm Level

2.13 One effect of the growing awareness of the sources of Japanese competitiveness was that, starting in the early 1980s, a concurrence began building among analysts and observers on the necessity for organizational reform within Western firms if they were to have any hope of competing against Japanese products.[66/] At the same time, a much more significant process of change was starting on the shopfloor and in the boardrooms of manufacturing companies in the U.S. and Europe. Western industrialists and managers began to alter fundamentally their opinions about the Japanese approach. For example, before visiting a variety of Japanese manufacturing plants, managers from General Electric in the U.S.

> "generally believed that the meaningful differences between Japanese and American manufacturing were cultural and environmental. By the end (of the visit), their opinions had changed. 'Nothing amazing was being done...We have known all along how to do these things but have lacked the discipline to follow through and do what we know how to do...It would be much easier for us if the differences we saw were technological or grand-strategy related...but they are not...The fact of the matter is that the Japanese don't work harder. They just work more consistently, and they work together.' (quotes from GE managers)"[67/]

2.14 The above sentiment is increasing among Western managers as understanding of Japanese managerial and organizational practices spreads via diverse conduits--visits to Japanese plants by Western managers; advice provided by management consultants and advisors with expertise in the new practices; seminars, workshops, and a variety of consciousness-raising activities undertaken by industry associations and university-based academics; and through the demonstration effect from Western firms and Japanese subsidiaries who are introducing the new practices in North America and Europe.[68/]

2.15 The main locus of change in Western industry continues to be in the motor vehicles sector, characterized by a "frenzy of adaptation" to the new standards of managerial best practice, to ensure their competitive

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66/ See Appendix I and the discussion and analysis in Abernathy, Clark, and Kantrow (1983); Piore and Sabel (1984: Hayes and Wheelwright (1985); and Cohen and Zysman (1987).

67/ Wheelwright (1981).

68/ Chapter I discussed how engineering firms have been forced to embrace the new practices as part of their efforts to assimilate advanced manufacturing technology. This process will continue, but diffusion of the new practices has taken on a momentum of its own quite distinct from the technological link, as firms increasingly appreciate the inherent value of organizational innovation.

survival.[69] Ford, of course, is the best known example of successful adaptation to the new practices. GM is the best known example of failure to adapt to the new practices, despite its tardy efforts to do so and its well-publicized collaboration with Toyota.

2.16 Organizational change in the auto components segment is perhaps even more frenetic. For the last five years, component firms have been under tremendous pressure from assemblers (both domestic and foreign) to adopt the new practices for consistent quality, on-demand delivery, and productivity-led cost reductions. There are indications that most of the major auto component firms in Europe and the U.S. are pursuing organizational change at some level (and in turn attempting to pass the lessons on to their suppliers).[70]

2.17 Non-auto segments of the engineering industry also provide ample firm-level evidence of adoption of new practices. Table 2.7 gives a compilation of results from well-known engineering sector cases of organizational change. Outside the engineering sector, large and small firms from virtually all segments of manufacturing and services are introducing the new practices.[71]

69/ See Hoffman and Kaplinsky (1988); Mitchell (1987); Bernstein and Zellner (1987); and Hampton (1987) for the most recent reviews.

70/ Womack (1987) describes exchanges between Toyota and a variety of U.S. components firms when Toyota was trying to determine the source of defects in the components it was receiving for use in NUMMI. The exchanges are enormously illuminating both about the pressure assemblers are placing upon suppliers to change, and about the fundamentally different nature of relationships between suppliers and buyers under the new practices. When Toyota asked how the supplier's plant was run, they expected full cooperation, as is the case with Japanese suppliers. The answer they moist often received was that "how the supplier's plant is run was none of Toyota's business!" Toyota's reply was in effect that "if you want a long-term relationship with Toyota, your business and Toyota's business are one. Maintain your present attitude and our relationship is over."

71/ Schonberger (1987) provides a listing of 84 firms that have introduced the new practices from more than 15 different sectors. See Helm and Buell (1987) on Kodak against Fuji; Work et al. (1987) on Goodyear Tire and Rubber Co.; Port (1987) for AT&T, Corning Glass, Dupont, Ford, IBM, Westinghouse and Hewlett-Packard; Schiller (1987) for GE, Whirlpool and Raytheon; Hoerr (1987) on the ACTWU and Westinghouse Furniture Systems; and Stavro (1986) on Caterpillar. See Fortune (December 19, 1988), "This Cat is Acting Like a Tiger" for Caterpillar's experience in revamping its plants and beating back the Japanese.

Table 2.7 Selected Examples of Gains from Organizational Innovation in U.S. and European Engineering Firms

Product	Time period	Inventory reduction	Lead-time reduction	Space saving	Labor productivity
Engine		15000 units	10 days	(stock turnover)	
Small machinery		$20m $3.5m	25 days 2 days	(delayed deliveries) 40% 2%	(hours per unit) 330 200
Tractors	1980-84	31% on average	significant	significant	40%
Auto components	1982-84	turns 1.9 4.0	1 month 1 week	25% and eliminated stockrooms	13% in direct labor

Source: Bessant and Rush (1987); Suzaki (1987)

2.18 Although anecdotal evidence is impressive, no comprehensive and reliable diffusion study on the spread of organizational innovations exists; thus, it is impossible to judge either the rate of diffusion or sector and country coverage.[72/] Many observers argue that U.S. and European firms still lag far behind Japan in the introduction of new practices and have not yet perceived their importance. Moreover, as discussed below, many problems have attended the introduction of these practices into Western firms. Finally, there is media and academic debate that Japanese management methods are so culturally specific that there is little chance of broad assimilation by other countries.[73/]

2.19 These qualifications have validity. Diffusion is probably slower, more difficult, and more uneven than case studies and the business literature indicate, and Japanese culture and conditions certainly have played a major

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72/ We cannot assess some of the more sweeping statements found in the literature, such as the recent claim made by a vice-president of Cummins Engine Co. who, on the basis of his direct experience, stated "that more than 75% of the tope 500 U.S. industrial corporations are now moving along new management lines." Piper (1986).

73/ See Johannson (1988) for reservations about the rated differences in the U.S. See Fukuda (1986), Murakami (1982), Kono (1982), Weiss (1984), and Matsumoto (1982) for a sample of the literature on the issue of cultural specificity, as well as the discussions in Piore and Sabel (1984) and Cohen and Zysman (1987).

role in shaping Japanese managerial philosophy.[74/] Since processes of paradigmatic diffusion from country to country take place over a long period, they may be obscure and unnoticed by the contemporary observer. Nevertheless, empirical evidence indicates that large parts of the new system and its specific practices are transferable to different countries and to firms operating in sectors greatly differing from the motor vehicle industry.

2.20 The reasons underlying firms' decisions to change their managerial philosophy are straightforward. Some firms must adopt the new practices to survive competition from the Japanese and the NICs. Others change because of demands for greater flexibility and higher quality in the marketplace or because they recognize, belatedly, that flexible automation cannot be exploited fully without a complete overhaul of organization and management practices. Perhaps the most telling reasons why many industrialists now are willing to change their philosophy are that the logic of the new principles is rooted not in theory but in clearly superior production practices whose implementation yields immediate, visible, and substantial benefits.

2.21 There is widespread and growing consensus that the process of inter- and intra-firm organizational change will be one of the central phenomena of global industrial development into the twenty-first century. This possibility raises immediate questions on the relevance of modern practices to the specific conditions of production in developing countries.

2.22 For a balanced assessment of the question of applicability, an examination of the new approaches to production organization from the standpoint of both theory and practice is necessary. Two bodies of knowledge can be consulted for this purpose. First are the writings--and experience--of the "practitioners," a small but influential group of managers, consultants, and gurus who have been instrumental in the spread and adoption of the new industrial organizational principles in the U.S. and Europe. The second source of information are the researchers and industry analysts who have studied the processes of organizational change and the problems and effects of firm-level efforts to apply the new practices. They provide studies less concerned with "nuts and bolts" and more focused on general lessons derived from systematic analysis of empirical evidence. To synthesize these distinct bodies of knowledge, we discuss in the remainder of this chapter the several principles and unifying themes that form the philosophical foundations of the new approaches to management and production organization. In Chapter III, the techniques and practices them-selves are discussed in detail.[75/]

74/ Piore and Sabel (1984) show how particular circumstances in the American economy heavily influenced the shape of the mass production paradigm and how its path of diffusion in other countries was determined by conditions in those economies. We would expect the same process to be at work in relation to the inter-country spread of the new practices.

75/ Much of this material will be known to those relatively few readers already familiar with these issues. They might chose to skip to the last chapter. For those not familiar with the nature and logic of the new practices, the following presentation will be enlightening.

Management as the Driving Force--the Workforce as the Source of Improvement

2.23 The strongest theme in both practitioner and analytical literature is that the new organizational practices will not be successful unless top management understands their logic and commits fully to the fundamental changes involved.[76/] This transformation involves pervasive shifts in the way managers view the production process; in their perceptions of responsibility and control; and in their personal and corporate ideology regarding management of the workforce. Managers must acknowledge that responsibility for most past and present problems does not lie with the workers but with the rules, procedures, working environment, and production systems that management itself has created. Perhaps even more difficult, management also must transfer an unprecedented degree of responsibility for quality, innovative effort, and production organization to line workers.[77/]

2.24 The philosophy underlying this approach contrasts sharply with standard (mass production) practice in the West. Its essence is that the most important source of gains in productivity and quality are the skills, knowledge, and expertise of the people directly involved in the production process day to day. Thus, rather than seeing workers as the cause of problems,

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76/ Achieving those changes is no easy task: The old idea that a manager's main function is to control workers is replaced with the concept that a manager should encourage employees to use initiative ... To accept the commitment model of work, managers have to go through a 'personal paradigm shift' which is a deep psychological process." Fraser, 1986, p. 78, quoting a U.S. food company executive with direct experience introducing the new practices.

77/ Schwarz, 1986 sums up the differences between the Western and Japanese attitudes to the workforce in an article that documents the success of Japanese managers introducing their methods in the U.S.: "The Japanese are saving a lot of time and money in the U.S. because they start with the assumption that their workers are intelligent, rational, motivated human being ... Western managers on the other hand often think they are dealing with dumb gorillas. Western firms have been forced to build a complex system to manage an adversarial relationship with its workers. The Japanese invasion may help bring peace."

management's job is to create conditions that encourage workers to apply their creative energy and skill to the solution of problems.[78/]

2.25 The Re-Education of Management. Much academic literature in this field emphasizes the need for management commitment but is devoid of suggestions on how to bring about this transformation, the most difficult step in the whole process. Some practitioners recognize this problem and argue that, as a first step, managers have to experience organized and structured re-education. This is necessary even with a genuine commitment to change because the new principles and their implications for action are so alien to standard practice that managers frequently do not know where to begin.

2.26 Management re-education can be undertaken by means of an arms-length approach, which involves management attendance at practitioners' seminars, visits to "converted" firms, and the close study of codified practices and principles in the "cookbooks" (case studies) available. Alternatively, companies can bring in outside consultants to advise and work actively with managers to implement changes.

2.27 Companies also can enter into joint ventures with firms already expert in the new practices. This arrangement allows managers to learn how the principles are applied, by being directly involved in their application.[79/]

78/ If we look back at the fundamentals of scientific management as laid down by Frederic Taylor, the differences in approach to managing the workforce are revealed starkly. According to Taylor, four principles were involved in "scientific management"--all intended to eliminate sources of worker power and control and enlarge the scope of managerial responsibility. Management had to absorb and codify the skills of workers and reduce these to rules. "All possible brain work should be removed from the shop and centered in the planning and laying out department." The increasing division of labor should lead to the separation of "direct" from "indirect" tasks such as machine set-up, preparation, maintenance and repair. Management should specify the tasks of the workers. All of this was to be achieved via the development of eight functional layers of management. See Hoffman and Kaplinsky (1987) for an extensive discussion.

79/ By far the best known attempt at joint venture learning is the GM/Toyota NUMMI project. GM entered into the project to master the Toyota production system, and Toyota got involved to learn how to transplant its system into the North American business environment. The project is expensive (US$200 million by Toyota and an entire plant by GM), but under Toyota management it has achieved world-class levels of productivity and quality. In the course of this, Toyota has educated more than 300 of its managers on training American workers, but GM has managed to train fully only 45 to 50 of its managers in the Toyota system. This might be because of the greater difficulty of GM's task (re-education of managers firmly entrenched in GM's mass production culture), or because the companies followed fundamentally different training procedures. This issue is worth further examination.

2.28 These management re-education methods have shortcomings that might prove particularly difficult to overcome in a developing country context (an issue returned to in the Conclusion). Whatever approach is selected, the aim must be to engage managers in activities that provide a definite and visible learning focus and that allow them to translate into practical terms what the new practices mean for the workforce and for the way production is organized in their plants.

The Quality Factor

2.29 A pervasive commitment to all aspects of quality at all levels of the firm is the second unifying theme of the new practices. The issue of quality has a long history in U.S. industry, beginning with a focus on "quality control by leading management authorities in the first decades of this century."[80/] Following this, the "quality assurance" era spanned the 1950s and 1960s, when concepts such as the cost of quality, total quality control, reliability engineering, and zero defects became popular. However, throughout the 1970s, the approach to quality in the U.S. was largely defensive (identifying rather than preventing defects); its attainment was a specialist function; and management was rarely concerned with it as a source of productivity gains and market share.

2.30 This was not the case in Japan. U.S. experts [81/] introduced quality techniques to Japan through seminars and workshops in the 1950s. These ideas were spread widely by the Union of Japanese Scientists and

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80/ Quality control as a concept was first introduced by Taylor (1919) and Radford (1922) and given the classic treatment by Shewart (1931). In these early texts, quality control was seen as necessary; it was carried out via inspection and was a specific function of shopfloor supervision. Shewart (1931) introduced scientific and statistical rigor into quality inspection, elevating it to a task worthy of specialized expertise.

81/ Deming, Juran, and Feigenbaum. Statistical and management techniques for pursuing these objectives on the factory floor were developed by people such as Juran (1951), Feigenbaum (1956), Halpin (1966), and Crosby (1979).

Engineers (JUSE) and the Japanese Federation of Economic Organizations.[82/] With the development of quality control circles and company-wide quality control in the 1960s, the Japanese approach became an all-embracing concept in theory and in practice.[83/] Quality as a source of competitive advantage was by then firmly entrenched as a principle preoccupation of workers, super-

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82/ See Garvin (1988); Walton (1987) and Deming (1982) for a discussion of the evolution of Japanese quality concerns. Deming (1982) cites how Mr. K. Koyangi (founder of JUSE) reported at the 1952 meeting of the American Society for Quality Control that great strides inn quality and productivity improvement had been accomplished by thirteen top Japanese companies, following top management attendance at the 1950 lectures--Furukawa Electric Company reported that within six months of applying the practices outlined in the lectures, it achieved a 90% reduction in rework in its cable and insulated wire plants, as well as a great reduction in the frequency of accidents; Tanabe Pharmaceutical Company, where productivity went up by 300% via process improvements, identified through the application of quality principles; and finally, Fuji Steel Co. reduced by 29% the amount of fuel needed to produce a ton of steel after only three months experience with quality control.

[This author notes that many plants in developing countries today operating with 1950s technology might well benefit from a similar commitment to quality.]

83/ Dr. K. Ishikawa introduced the concepts and techniques of quality circles in Japanese industry in 1960. By 1962, some 100,000 employees were involved. By 1978 more than one million workers were involved in QCs; and by 1984 the figure had risen to 1.5 million. This is impressive but the important point to note is that quality circles are not crucial to Japanese quality. They are simply one more mechanism employed in a constant search to improve quality as part of an overall philosophy. However, as Lawler and Mohrman, 1985 show, western firms missed this point entirely when they aggressively pursued introduction of quality circles as one-off devices to squeeze moire productivity out of workers but did so without a genuine management commitment to quality. Most U.S. quality circles, in effect, self-destructed after a short while because of management myopia on this issue.

visors, and senior management--an approach that has proved enormously successful.[84/]

2.31 Elements of the Quality Philosophy. Four elements underpin the approach to quality control now being widely pursued by Western firms. First, the competitive benefits arising from quality relate to both consumer satisfaction and productive efficiency. Quality of product and service confer demonstrably decisive advantages in the marketplace, and these concerns typically underlie calls for firms to pursue the "strategic management of quality." Less well appreciated is the fundamental point that the improvement of quality leads to measurable cost reductions and productivity improvements.

2.32 The "costs" of quality include prevention costs, appraisal costs, internal failure costs, and external failure costs. On average, about 40% of total manufacturers' costs relate to quality. Eliminate quality problems, and total costs decline substantially, both through eliminating activities associated with quality costs and through improvements in the production process.

2.33 Second, quality improvement is not a one-off activity but a continuous process. Improve quality continuously, and costs go down continuously. The aim of quality improvement "... is perfection; anything less is regarded as ann interim goal, to be succeeded by progressively tighter standards ... Until defects can no longer be found."[85/] This attitude, of course, runs counter to the common Western assumption that quality costs money

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84/ It has not all been easy. Walton (1982) makes clear that many Japanese companies had to struggle for years to get their quality practices to acceptable levels. For example, the Hiroshima plant of Japan Steel Co. faced many typical problems with quality and widely variable demand patterns for its machinery products that were causing it to lose profitability and market share inn the 1970s. In 1977, the company embarked on a TQ effort that involved the use of JUSE consultants to train staff and line workers in the use of various SQC measures, the introduction of QCs and monetary rewards for employee suggestions.

Between 1978 and 1981, suggestions per employee rose from 5.6 per year to 28.5 per year, the cost of defects as a proportion of sales dropped from 1.57 to 0.4, production rose by 50% while the number of employees declined from 2,400 to 1,900, throughout improved 100% and the accident rate dropped from 15.7 to 2.3 per million man hours. The Hiroshima plant won the Deming price in 1979, Japan Steel instituted TQ practices on a company wide level at that time and itself won the Deming quality prize in 1983.

85/ Garvin (1988).

and that there must be a point at which improvement stops, because further improvement will not pay for the cost of improvement.[86/]

2.34 The third element is that the problems that cause defects are much more cheaply and effectively dealt with at their point of origin rather than later via inspection, rework, and field correction. The economic rationale for this is straightforward, and the costs of not ensuring quality "at the source" are staggering. Figure 2.4 (prepared by General Electric) captures this point. The costs of error rise by an order of magnitude each time a product or component moves a step further along the production process. Thus, an error costing US$.003 to correct at the supplier stage costs US$300 to put right by the time the product is in the field.

2.35 The fourth and final element in the quality equation is that defects can arise at any point in the production process--design, materials, machinery operation, poor training of operators, packaging, movement, and sale of final goods. Thus, all staff and all functions must be involved in the prevention and correction of defects and the improvement of quality, with two groups frequently singled out for special emphasis. Line workers play a particularly important role in the pursuit of quality, not because they cause defects but because they know the production system and can identify causes of defects better than anyone else. Design engineers also are a critical element in quality concerns. This is not just because of the costs of faulty or

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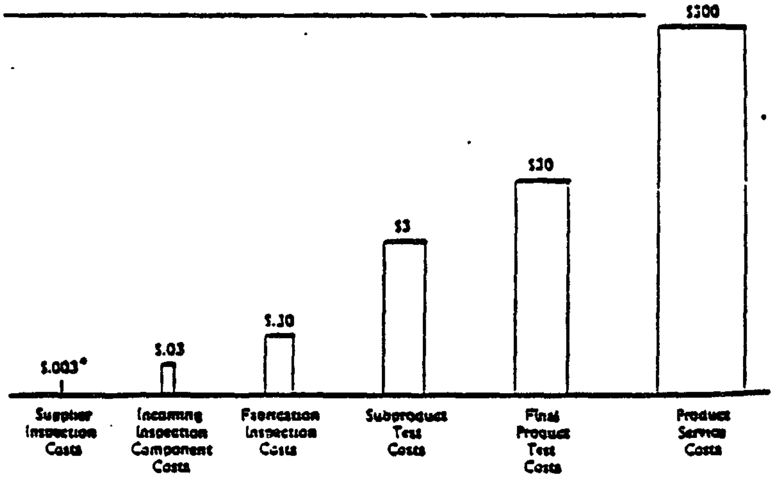
86/ Deming (1986), Walter (1986), Hayes (1981) and Garvin (1988) all discuss this aspect extensively and give examples of why the logic in fact runs the other way. The concept that the continual improvement of quality leads to the continual improvement of productivity and the reduction of costs is a difficult one to grasp for traditional managers (and economists brought up on marginal cost analysis). How does this happen?

"Quality is achieved by improvement of the process. Improvement of the process increases uniformity of output of product, reduces re-work and mistakes, reduces waste of manpower, machine time and material and thus increases output with less effort ... Defects are not free. Somebody gets paid to make them and it costs moire to correct them than to make the product inn the first place ... From 15 to 40% of the manufacturer's cost of almost any American product that you buy today is for waste embedded inn it--waste of human effort, waste of machine time, loss of accompanying burden.

Reduction of waste transfers man-hours and machine-hours from the manufacture of defectives into the manufacture of additional good product ... the capacity of the production line is increased. The benefits of better quality through process improvement are the long-range improvement of market position, greater productivity, much better profit, and improved morale of the work force because they see management is making some effort themselves, and not blaming all faults on production workers. (Deming, 1982).

unappealing designs but because, as mentioned in Chapter I, manufacturability is seen as a quality and, therefore, a design issue.[87/]

Figure 2.4 Escalation in Cost of Errors Down the Production Line



* Estimated cost per defect per product

Source: cited in Garvin (1988)

<u>The Elimination of Waste</u>

2.36 The third common theme in the new practices concerns the problem of <u>waste</u> in production--an issue first raised in the 1920s by Henry Ford. Waste is conceived as "anything other than the minimum amount of equipment, materials, parts, space and workers' time which are absolutely essential to add value to the product."[88/] Any action component or procedure that does not contribute to value must be eliminated. The origins of current concern with waste derive from Toyota's efforts in the 1950s and 1960s to cope with the introduction of product variety as a competitive weapon in gaining market share in the Japanese auto industry.

87/ A corollary of the idea that all parts of the firm are responsible for quality is that the customer determines and defines quality. The concept of customer in the context of the new practices is broad, with the final retail customers being the ultimate arbiter of quality through their buying decisions. At the same time, every worker at every stage in the production process is both "customer" (of the output of the previous stage) and "supplier" (of inputs to the next stage). Each supplier must strive to satisfy the quality demanded by each customer in the production chain. See Walton and Deming (1982).

88/ Suzaki (1987).

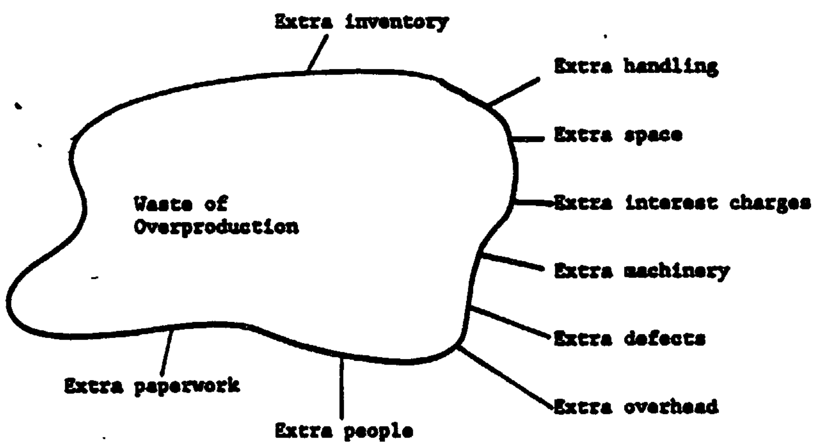
2.37 Though most frequently referred to in the context of inventory reduction within the just-in-time (JIT) production system, the focus on elimination of waste has numerous dimensions that underpin its role as a unifying concern. Figure 2.5 lists multiple sources of waste. These exist in all factories, not just because of sloppy management but because they are built into the system and procedures of the mass production model (emulated even by firms not involved in mass production).[89]

2.38 The different categories of waste all generate by-products that inevitably drive up costs and reduce productivity. Figure 2.5 captures this aspect of waste from overproduction, but similar costs could be identified each of the various categories. As with quality problems, the elimination of waste reduces costs and improves productivity.

Figure 2.5 The Seven Wastes

1) Waste from overproduction
2) Waste of waiting time
3) Transportation waste
4) Processing waste
5) Inventory waste
6) Waste of motion
7) Waste from product defects

Waste Resulting from Overproduction:



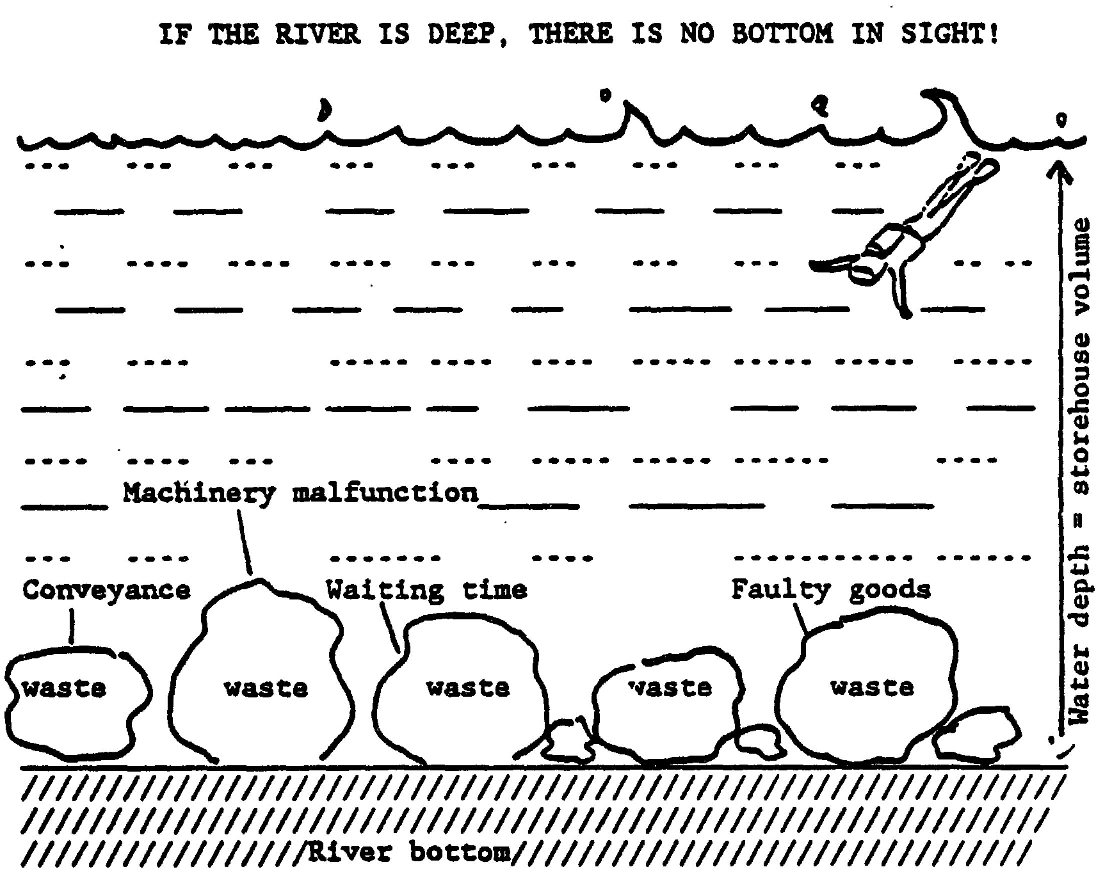
Overproduction creates more problems and obscures the real cause of the problems.

Source: Suzaki (1987)

89/ The function of inventories in mass production is to allow continual operation of the plant. The organizing principle at work is a supply-driven one, with all attention focused on keeping the line running at any cost. Quality concerns are secondary, and relations with suppliers are adversarial because price is the major determinant of contract placement. To this end, large inventories of components and work-in-progress is the norm in case anything goes wrong in terms of (frequent) poor component quality, late delivery, equipment breakdown, etc.

2.39 Deliberate steps to identify the causes of waste will eliminate waste-related costs. Some of these steps are straightforward, such as the establishment of procedures for workplace organization. Others are more difficult, such as the elimination of inventories and the reduction of set-up and changeover times. Figure 2.6, taken from Toyota's 1960 Industrial Engineering Manual, illustrates how inventories mask various forms of waste. Management must systematically drive down inventories (the water level in the figure) to reveal defects in the system (the rocks), rectify them, and capture savings in WIP.

Figure 2.6 Toyota's View of the Inventory Problem



Inventory changes with the production syst.m

Inventory changes with the manufacturing method

Source: Toyota Industries

2.40 Tying it all together. Although it is unlikely that most Western, developing country, or Japanese firms will ever approach the level of sophistication of Toyota or Honda, it is useful to show briefly how the principles of quality improvement and waste elimination are put into practice in a worker-led production process. Basically, two systems work together, JIT inventory control and total quality control (TQC). The basic features of JIT and many aspects of TQC systems emerged initially in response to specific conditions in the Japanese auto sector.[90/]

2.41 JIT. The critical organizing principle of JIT emerged through a long process of trial and error from the 1950s to the 1970s and is elegant in its simplicity. Production lines, originally structured according to mass production principles, were reorganized so that work passed from one stage to the next without intermediate storage. Machines (or people) at one step thus produced the pieces required for the next step, from fabrication through final assembly. The ideal lot size is one piece at a time--i.e., job lots of one. Consequently, work flow is on a "pull-through" basis, with production at any stage occurring only when the next stage in the line is ready to receive the output of the previous stage. Tool and line changeover is short, through

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90/ In 1950, Toyota, soon followed by other firms, made a strategic decision to introduce product variety to gain market share in the auto sector, since it could not compete via the pursuit of scale economies. However, the firm had to deal with a range of problems arising from the decision to produce a variety of models in small lots. Product variety introduced complexity into a production process whose equipment was typically designed for high-volume dedicated production of, basically, only one model. Product variety demanded that what was, in effect, a demand-driven production process be highly flexible to minimize inventory carrying costs and the costs of line and tool changeover, both major categories of costs inherent in (supply-driven) mass production.

Reducing production runs exerted great pressure on materials handling because of the resultant need to handle and store the multitude of parts required to make a variety of products. Materials had to arrive at just the right station at just the right time. The total volume involved could not be stored near the line, the case in mass production. Otherwise, the advantages of small-batch production are lost and machines and workers sit idle. Hence, the marketing decision in the 1950s that targeted product niches and demanded production line flexibility was also the first step toward the JIT system.

engineering "quick change" capabilities, thus making it economical to run small lots.[91/]

2.42 TQC. This system is most visible in workers' attitudes and responses to the quality of components coming to and leaving their work-stations; for example:

> "Say that a worker makes one piece and hands it to a second worker whose job is to join another piece to it, but the second worker cannot make them fit, because the first worker made a defective part. The second worker wants to meet his quota and does not like being stopped, so he lets the first worker know about it right away. The first worker's reactions are predictable; he tries not to foul up again--and tries to root out the problem that caused the defective part.
>
> The typical western way by contrast, is to make parts in large lots--two weeks' worth maybe. The second worker might find 10% to be defective but he does not care. He just tosses a defective part into a scrap rework bin and grabs another. There are enough good ones to keep him busy, so why complain about defectives! The Japanese cut the wasted hours and wasted materials by not allowing large lots of defectives to be produced."[92/]

2.43 A Schematic View of JIT/TQC. Figure 2.7 shows a JIT/TQC production line as a cause-effect chain reaction of events. The starting point for the chain reaction is the deliberate lot-size reductions shown in the double-bordered rectangle A. This forces a reduction in set-up times to facilitate fast changeover (not shown), then leads to less inventory carrying costs (A) and reductions in other indirect costs (I).

2.44 Smaller lot sizes lead to a round of direct and indirect savings due to scrap and quality improvements (B, C and D). This occurs because of the interaction between workers over quality, depicted by the E-F feedback loop. Workers (organized in small teams), supervisors, engineers, all search for solutions to delays or quality problems which inhibit the smooth flow-through ideas for improvements because of their higher awareness of the

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91/ In mass production, a change in the specification of output necessarily involves the time-consuming task of resetting (inflexible) machinery. The costs involved in this (due to lost output) are very high and the changeover variable one of the major factors accounting for scale economies in mass production--which meant that in the early 1980s a new engine production facility would cost in the region of $500 million. Flexible product schedules would prove an extremely costly innovation unless changeover times could be reduced. Abegglen and Stalk, 1985, describe in detail precisely how Toyota set about doing just this in the 1950s. The now legendary reductions in changeover times were the result. Changeover times on multi-ton does and presses that on western mass production lines took 8 hours, even days sometimes, to switch over were reduced to minutes.

92/ Schonberger (1982).

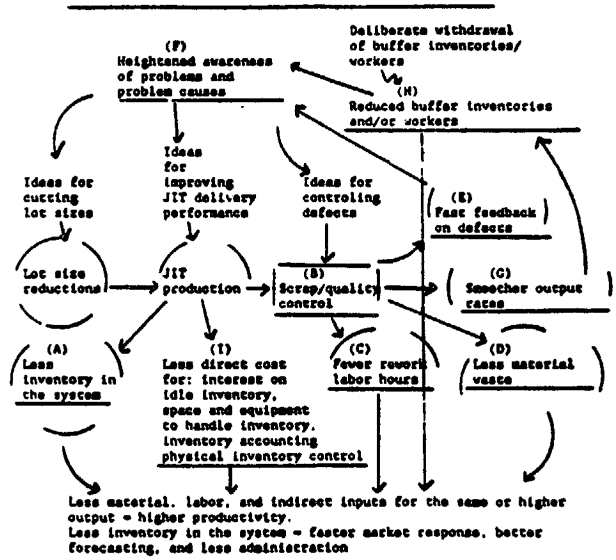
consequences. "Each good idea ripples through the JIT cause-effect chain. Improvement feeds upon improvement."[93/]

2.45 The right side of Figure 2.7 shows the effects of perhaps the most surprising of the techniques for managing the JIT system. On its own, the lot-reduction process moves the system toward a smooth flow of output. However, there are (and always will be) irregularities; in the normal course of events, buffer inventories build up between stages and cushion the effect of production irregularities. Japanese managers eliminate these buffers. As soon as the system settles down, they deliberately remove buffer inventories and/or workers (H) to set the cause-effect process off again. The result is a continual round of productivity improvement--and the relentless heightening of performance pressures on the workers.

2.46 In this model, TQC greatly enhances the quality control aspects of JIT via its effects on B, C, D, E and F. "Quality at the source" captures the TQC practice of immediately solving problems as they appear, with workers taking steps to correct the defects or problems.

2.47 In the model represented in Figure 2.7, the JIT system clearly is more than an inventory control system. It functions also as a quality and scrap control tool, as a technique to help in reconfiguring plant layout, as a means of raising process yield, as a method to achieve production line balancing, and as a mechanism for employee involvement and motivation. The output of the self-sustaining JIT/TQC system is thus a continual round of improvements in productivity and product quality. Of course, this system did not develop overnight, nor is it practiced fully in most plants. However, the JIT/TQC model has become the new best-practice standard that most Western engineering (and manufacturing) firms will spend the next twenty years emulating.

Figure 2.7 JIT and TQC as an Integrated System



Source Schonberger (1982)

93/ Schonberger (1982).

CHAPTER III

ORGANIZATIONAL INNOVATION IN PRACTICE

3.01 This chapter focuses on the specifics of the new organizational practices, giving the reader sufficient detail about the substance as well as the underlying theory of these practices. Because of this concern with detail, Chapter III concentrates on particularly relevant areas.[94]

3.02 The discussion in this chapter is organized under four aspects of management: management of the workforce, of machines, of the production process, and of relations with suppliers. Under each topic is a discussion of the techniques that have been developed to bring the principles discussed in Chapter II into practice. The issues raised pose challenging implications for developing countries and for firm and country strategies for industrial competitiveness. These are discussed selectively as they arise, with most analysis of these issues presented in the last chapter.

Managing the Workforce

3.03 Effective management of worker relations within the firm is perhaps the most critical area because of the key role of the workforce in the introduction and daily implementation of the new practices. Both workforce and management have to be prepared to alter attitudes. The complex way in which individual, corporate, and social characteristics interact within the workplace makes it difficult to specify steps or techniques, however. Case studies show that worker suspicion of management objectives has represented an obstacle to change, sometimes unjustified; in other cases, worker resistance has been legitimate because management has fraudulently donned the attitude of a "new era of cooperation with labor" while in effect pursuing the old confrontational policies.[95]

94/ Much of what is discussed is drawn directly from the work of practitioners, such as Deming (1982, 1986) and Schonberger (1982, 1987).

95/ Hoffman and Kaplinsky (1987) document a number of these instances in the U.S. motor vehicle sector, most of them involving G.M. See also Shaiken (1985), Katz (1985) and Jones and Scott (1987). There also have been cases reported of labor suspicion and antagonism to management practices in the U.S. subsidiaries of Japanese firms. One of these relates to an extreme episode of labor-management strife at a Sanyo T.V. plant in Arkansas. When it was initially taken over by Sanyo in the late 1970s, the company received rave reviews (Schonberger, 1982) for JIT/TQC improvements that supposedly had positive effects on productivity and employee morale. Carson (1986) however reports a complete breakdown in relations, two vicious strikes, and quotes labor representatives who claim that the much publicized productivity improvements mainly came from an old-fashioned speed-up of the assembly line. Clearly in this case and in others, more information is needed to make a judgment.

3.04 Creating the Right Conditions. Once the re-education of top management is well underway or completed, the practitioners propose a number of macro-management steps to introduce change and to begin convincing the workforce of management's seriousness and commitment to the new approach. Some of these steps are one-off measures introduced as part of the start-up process, but others are meant to take place over much longer time or on a continuous basis.

3.05 Forming teams and projects to manage change. The first step is to create a team structure within the firm to ensure implementation of proposed changes. Teams should include people with direct and indirect responsibility for the problems being tackled. Management-led teams will play a major role in the early stages, but line-worker teams, formed for problem solving or as part of the reorganized production process, should handle shopfloor projects.[96] A central idea here is that changes should be introduced incrementally via small, manageable projects that follow a "learning" cycle of observation, planning, action, feedback, and reaction.[97] The ideal practice is to have a series of projects always underway in all parts of the company, and that are aimed at improving performance via a manageable, attainable process.

3.06 Inform the workforce at all levels. The second step is to use seminars, workshops and discussion groups to inform the entire workforce about why changes are necessary, what principles are behind them, how changes are to be implemented, and what the effects are likely to be on the firm and its workers. The aim is to create a critical base of people in the firm who understand and support the changes.

3.07 Open channels of communication. This education process must not be a one-way process. Management at all levels needs early exposure to the comments and criticisms of the workforce about the way the firm is run, its products, processes, and working conditions. Management has to demonstrate its willingness to respond positively to these criticisms. The aim is to lay the groundwork for daily communication across all staff levels on production problems and solving them. The problems that arise from lack of staff communication and responsiveness are legendary and well-documented, but such

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96/ The most common model for organizing workers into teams in the engineering industry is teams consisting of five to seven members led by a team leader who usually has no direct production line responsibilities. The team leader is responsible for activities performed by supervisors, industrial engineers, QC staff, and other specialists. These include organizing the team's production and project responsibilities, as well as quality control audits, team training, work standardization, preventive maintenance, and paper work. The team leader also fills in for absent team members--thus creating strong peer pressure against absenteeism.

97/ Deming, Suzaki and other practitioners use what is known as the Shewhart Cycle to illustrate how this learning process moves forward.

situations persist throughout industry.[98/] A crucial part of any attempt to introduce the new management practices is to open communications among staff and to create a sese of mutual responsibility and shared goals. Bringing managers and engineers physically and mentally down to the shop-floor--desks and all--so they can respond more effectively to line workers and solve production problems is one solution.[99/]

3.08 Eliminate fear in the workplace. Two sets of problems characterize working conditions in most Western--and developing country--plants and factories. First, too often employees are afraid to point out problems, to ask for help, or to make suggestions. Second, many obstacles exist in the working environment that prevent workers from doing their jobs properly and taking pride in their work.

3.09 Management can take a variety of specific steps to identify and overcome these problems. These include addressing physical problems, such as repairing faulty machinery, clearing up crowded working areas, or even halting mindless exhortations to work harder. But the problems often derive from management's adversarial relationship with its workforce, and solving such

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98/ Typically, purchasing departments place orders based on written specifications they do not understand, buyers do not understand how the materials they buy are used, designers constantly come up with products that give engineers problems, engineers are often made to feel unwelcome on the shopfloor. Walton (1986) gives a description of what happened when a Honeywell plant in Massachusetts "launched a wave of task-oriented project teams that cut across department lines. As soon as departments started talking to each other, some of the thorniest problems dissolved. There was, for example, a case of delays on the Honeywell loading dock. Tracking the shipments, a team discovered that there were traffic jams when outgoing orders arrived simultaneously at a single freight elevator. An elevator schedule was drafted immediately... In a related problem, a team learned that orders often went to the wrong destination because of labels that were difficult to read, for any number of reasons ranging from sloppy handwriting to smeared printing. Sometimes the labels were slapped into a side of the box that was hidden when the items were not properly stacked. Eventually a computerized system was introduced for labelling and instructions were issued for positioning the labels."

99/ Schonberger (1986).

problems will require actions that fundamentally alter the climate of work.[100/]

3.10 For example, workers must feel secure about making suggestions, offering criticism or asking for help from supervisors--without fear of retribution. Supervisors must focus on quality as their main objective and must take problems on quality to upper management--and expect action. Managers, supervisors, and engineers also must learn that their primary attitude vis-a-vis the workers is to be supportive rather than dictatorial. Performance incentives tied to quality and skill acquisition should replace numerical quotas and output targets. This will stimulate workers to aim for quality, pursue further training, and become active in improvement efforts. The practitioners' literature provides examples that demonstrate how common and costly problems rooted in fear are, and the gains that accrue when there is a conscious attempt by management to deal with them.[101/]

3.11 Institute adequate training and set clear performance standards. One of the most common causes of production problems is insufficient worker training and guidance because supervisors are more concerned about increasing production or because management has not clearly defined quality and output standards. A training period must be sufficient to qualify the worker fully for the job. Quality and performance standards must clearly define what is expected of the worker, and there must be explicit provision for continuous training of workers to upgrade skills and develop capability to handle malfunctions.

3.12 Provide Skills and Incentives. Beyond addressing fundamental issues of labor-management relations (even more problematic in developing

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100/ Deming (1982 and 1986) is one of the few practitioners to tackle this issue head on. A quote from Deming (1982) and a newspaper reference illustrate this point about fear: "The economic loss from fear is appalling. People are afraid to point out problems for fear they will start an argument, or worse, be blamed for the problem. Moreover, so seldom is anything done to correct problems that there is no incentive to expose them...they re afraid superiors will feel threatened and retaliate if they are too assertive or ask too many questions...They are afraid to admit they made a mistake, so the mistake is never rectified. In the perception of most employees, preserving the status quo is the only safe course." Schandler (1981) cites a U.S. government survey of 13,000 randomly selected employees of 15 government subcontractors. Of the 8,600 who responded, 45% (4,000) said they had personally observed or obtained direct evidence of wasteful or illegal activity in the last 12 months. One in ten claimed the cost of these events was in excess of $100,000. However, only 30% who claimed knowledge of wasteful activities reported this to anyone else. About 73% of those who failed to report an impropriety said it was because they "did not think anything would or could be done to correct the problem." Another 20% said they didn't say anything because it was "too risky."

101/ Walton (1987) provides a number of case studies that show how management has attempted to deal with the issue of fear in the workplace.

countries), four other points need to be made about this topic. The first relates to the shopfloor organization of workers. The basis for craft/job distinctions disappears when workers are multi-skilled and perform a variety of tasks. Typically, this means the negotiated disappearance of the job classifications so common in Western plants. One example of this is at the NUMMI plant where there are only four job classifications compared to 183 at GM's Massachusetts plant organized along traditional lines.

3.13 The second point relates to the need for continual improvement of machines and processes. Production under the new practices is highly engineering-intensive because of continuous problem-solving and machine alteration efforts. Firms must use their engineers more intensively and effectively. More engineers per worker are necessary under the new practices; and the ratio of engineers to production workers is likely to be much higher than current ratios typical of Western and developing country plants.[102/]

3.14 Third, under the new management philosophy, production workers are central to quality control and productivity growth. To fulfill this function, their skill base has to deepen and broaden (to meet quality control responsibilities, allow multi-machine/assembly operation, lead improvement projects). Table 3.1 captures the transition in worker skill levels from traditional practices to the new systems. Average entry-level education and skill levels need to be higher than under the old practices. Firms need access to considerable training resources in order to raise workforce skills to the levels demanded by the new system.

3.15 Fourth, incentive pay schemes are as important under the new approach as they are under traditional practices. The major difference under the new system is that workers are rewarded for producing quality goods, for offering suggestions for improvement, for attaining higher skill levels, and for achieving productivity gains. They are also compensated for length of service. Many ways exist to structure such a merit-based payments system; the key feature is to make employees aware of the connection between performance and pay.[103/]

102/ Weiss (1986). The same phenomenon is identified in Jaikumar's study of FMS usage in the U.S. and Japan.

103/ Under the old practices, firms pay the same hourly wages to their employees. Incentives offered are for production (incurring inventory costs for the firm) or to overcome management mistakes (work overtime to get late orders out or to replace poor quality products.

Table 3.1: TRANSITION IN EMPLOYEE SKILLS
UNDER NEW ORGANIZATIONAL PRACTICES

Old	New
	Machine operation
Skill is in the set-up	Skill is in simplifying the set-up
Sometimes set-up technicians or engineers are needed	Operators lead projects; technicians and engineers help
Operator watches machine run	Operation is a well-timed routine; operator is thinking about next improvement
	Assembly
Assembly jobs were simplified so unskilled labor could perform them	Assemblers acquire: o multiple job skills o data collection duties o diagnosis & problem-solving talents

Source: Schonberger (1986), p. 38

3.16 Finally, although incentives have a role to play in encouraging worker participation and attention to quality, they need augmentation from an effective supervisory structure. This implies supervisor re-training and re-orientation toward quality and away from increased output alone. Japanese firms and Western companies that have implemented the new practices have devised various techniques to stimulate management toward quality and continuous improvement.[104]

Managing Machines

3.17 The new organizational practices have a direct impact on virtually every aspect of firms' operation, purchases, maintainance, and improvement of machinery. Total preventive maintenance (TPM) is at the heart of this concept. Under a full JIT/TQC production system, the need for completely reliable machines capable of producing perfect quality output is paramount--because machine-related downtime or defects soon cause stoppages. Japanese industry's early concern with quality and quick change-over led to a set of practices that now constitute TPM. The two most significant aspects of TPM are (i) that maintaining machines in perfect quality makes good sense under any circumstances, and (ii) that such practices are largely common sense and transferable to any situation where operator-controlled machinery is used--provided there are appropriate training and working conditions.

104/ Schonberger (1986) contains a number of examples on the day-to-day use of these techniques by management in small companies.

3.18 Input from machine operators for TPM is wide ranging and includes the following basic steps:

- o Daily checking of machines, involving operator checks on basic functions and carrying out a number of minor tasks such as cleaning, oiling, tightening, adjusting, sharpening
- o Keeping careful TPM records that include details on hours of operation, preventive maintenance schedule, and the results of tool, performance, and quality checks--all essential for keeping track of major maintenance procedures
- o "Good housekeeping" of the machine areas, which involves cleaning the area as well as taking care of tools and setting up.[105/]

3.19 For the maintenance crew under TPM, similar procedures need to be followed. Figure 3.1 captures the central principle of the "five whys"--in practice there should be persistent questioning to identify causes and specify solutions to problems. Figure 3.2 shows how the operator and the maintenance efforts work together in TPM to prevent machine breakdowns.

3.20 Constant improvement of existing machines. Beyond TPM implications for operator training and skill demarcation, there are a number of other machinery aspects under the new methods of organization, many linked directly to the requirements imposed by the new practices.

(i) Attaining a quick changeover capability means that equipment often has to be modified; in many firms this can be a major engineering job when the machinery varies by year, manufacture, and operating parameters, all of which have to be standardized.[106/]

105/ In addition, machine operators are expected to be alert for unusual sounds or machine behavior that indicate wear or the need for repair. Operators are expected to carry out minor repairs, such as changing and tightening belts, replacing oil seals, even changing motors and bearings--usually simple tasks that do not involve major maintenance. Inherent is the assumption that workers will come to feel pride in their responsibility.

106/ Hall (1981) relates that "when the Japanese explain in detail how they achieved their big increases in productivity, the biggest war stories from the plant floor involved hard fought battles to reduce set-up times on a piece of equipment at first regarded as an insurmountable obstacle. Accounts of these battles detail changing the design of bolts, and the fit of pieces together on the machine, and the building of special tools to speed changeover."

Figure 3.1 Example of the Applications of the "Five Whys" Principle of Machine Maintenance

Problem: Malfunction of digital controller for NC machine

Why: Defective printed circuit board

Why: Lack of cooling

Why: Lack of air

Why: Lack of pressure

Why: Dust on filter

Solution: Clean filter every month

Source: Suzaki (1987), p. 116

Figure 3.2 How to Prevent Machine Breakdowns and Trouble

Maintain the normal machine conditions	• inspection • cleaning • tightening bolts • maintain correct operating procedures
↓	
Detect abnormal conditions as early as possible	• inspection/use of operator's five senses • inspection/use of diagnostic equipment • by maintenance crews
↓	
Develop and implement counter-measures to regain the normal machine conditions	• ask why, five times • develop new standard

Source: Suzaki (1987), p. 114

(ii) Maintaining production line flexibility means that machines need to be light-weight, in order to be moved easily, with fixed storage racks and conveyor systems eliminated or minimized.

(iii) In keeping with the JIT principle of producing only as much as needed, machines are operated at low speeds or, if there is no immediate demand, not at all (anathema to the Western mass production tradition of pushing out the product)--thus extending machine life, reducing breakdowns, and preventing inventory buildup.

(iv) Problem-solving under the pursuit of quality implies a continuous process of machine improvement and adaptation that is likely to be engineering intensive. The Japanese have a word, kaizen, which connotes a philosophy distinct from the search for high-tech quantum leaps in productivity gains and which stresses the historical importance of incremental productivity gains through organized learning.

3.21 Kaizen and the new practices also imply different criteria regarding capacity expansion and mechanization. Stemming from gains from flexibility, the new approach dictates that capacity expansion should be pursued incrementally by adding general or special purpose low-volume machines. Small volume, modular machines can be added as sales grow. They are cheaper, incur lower downtime costs, and provide the crucial flexibility.

3.22 Automation versus improvement. Under the new practices, the rationale for scrapping conventional machinery in favor of more automated technology also needs reexamination. Equipment in most factories has been badly neglected and its capacities poorly exploited. Thus, there are so many wrongs to be corrected that (a) the potential for gains in productivity and quality is enormous and sustainable over a considerable period, even in the face of automating competitors; and (b) if more automated and expensive equipment is acquired without reforming bad organizational practices, the equipment will fail to overcome the original problems of poor quality and low productivity.

3.23 Instead, new maintenance and quality control procedures can make current equipment reliable in a uniform, dependable cycle with no diminution of quality--and a likely substantial rise in productivity. In addition, the introduction of work standardization and pre-automation improvements can standardize and shorten reach and flow distances and make tools, parts, design packages, racks and fixtures easily accessible. These are all aspects of operations that contribute to improved efficiency without resorting to automation.107/

Managing the Production Process

3.24 Production line reorganization and materials movement. The major physical change under the new approaches involves a shift from a process-oriented to a product-oriented production layout. Production lines in engineering firms are typically organized as job shops, with equipment arranged by process. All the milling machines are together as are all lathes and presses. Work usually goes back and forth to allow completion of different operations. Such clustering, illustrated in Figure 3.3, creates many conditions inimical to organizational flexibility.108/

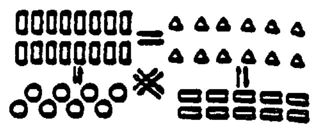
3.25 The ideal under the new approaches is to organize by flows rather than by processes, with sets of closely related activities grouped into product families. Workstations are close, so that work can pass between workers without intervention. Various configurations of processes organized by flow are depicted in the lower part of Figure 3.3. Figure 3.4 shows how the flow principle was applied in practice in a Rockwell manufacturing plant in the U.S.

107/ Chapter II pointed out that many Western firms have either eliminated or greatly reduced their requirements for automation technology after pursuing practices along these lines. The same situation almost certainly applies in many Third World firms, where the belief is that automation is the only means for survival. Indeed, as discussed in the final chapter, the logic of the new machine practices raises fascinating questions about the way Third World governments and firms, as well as development economists, planners, and international agencies, approach issues of competitive strategy. This is not only in response to automation in the industrialized countries but also in relation to plant operation, worker training, R&D, techniques, supplier selection, technology transfer, project design, etc.

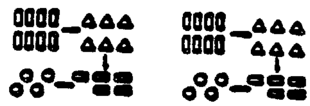
108/ Schonberger (1986) emphasizes in particular that perhaps the main drawback of clustering is that it tends to create a "gang" or "us and them" mentality among workers, which translates into a tendency to blame others for problems and a reluctance to take action to overcome the assumption that the responsibility lies elsewhere. When work stations are distant from suppliers, coordination of workflow is difficult and impedes rapid communication between workstations, which is crucial to flexibility. Product flow is long and involves much handling, thus increasing chances for damage; inventories build up, thereby hiding defects and evidence of their causes; inventory storage crowds the work area, as do the carts and other implements required to move it from one site to another.

Figure 3.3 Examples of Clustered Production and Flow Lines

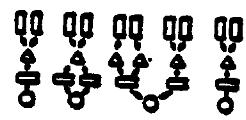
1. Clustered, jumbled
    - Clusters of generic workstations
    - No attempts to organize by product flows
    - No easily identifiable flow path, or organization contrary to flow path



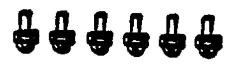
2. Clustered, flow-line
    - Clusters of generic workstations
    - Organization by product flow



3. Cellular
    - Unlike workstations grouped into cell to produce a product family
    - Only one workstation of a type, except where more needed for balance
    - Cell-to-cell organization by product flow



4. Unitary machine or assembly station
    - Complex module/product made at one machine, station, transfer line



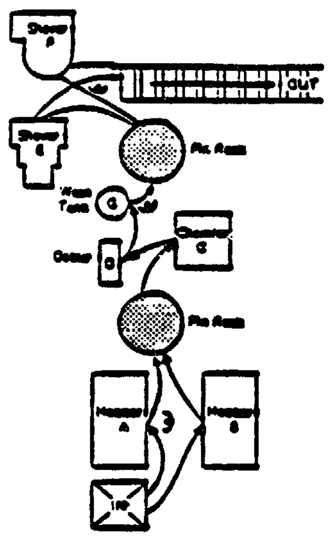
5. Dedicated flow-line
    - Unlike-workstations grouped into flow-line
    - Only one workstation of a type, except where more needed for balance
    - Organized by flow of a single product or a regular mix of products

6. Combined
    - Mixture of any of the above for a product or group of products

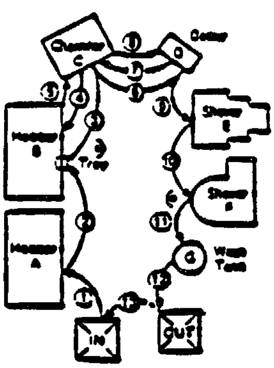
Source: Schonberger (1986), p. 105

Figure 3.4 Reorganization of Production Line and Gains Achieved, U.S. Components Firm

Before



After



Summary of Improvements

	Before	After	Improvement
Floor space	1148 sq ft	720 sq ft	37%
In-process inventory	4000 pcs	10 pcs	99%
No. of operators	2.7	2	25%
Output per person	168	217	23%
Scrap	100 (indexed)	28 (indexed)	74%

Source: Suzaki (1987), p. 81

3.26 Under flow-line arrangements, a workstation is close to both the source and destination of its product. The worker becomes part of a group with responsibility to set and meet objectives (for which group members may be rewarded) rather than just one of many workers performing repetitious tasks. If problems arise that impede work flow within the group or between groups, communication occurs quickly, followed by immediate efforts to solve the problems--or else production soon stops. In effect, "centers of responsibility" clear up problems between the shopfloor and other activities such as procurement, shipping, and design because all operations are physically or operationally closer together.

3.27 Lot and inventory reduction. Two other essential tools for bringing the production process on-line are lot reduction and inventory reduction. Although the ideal of lot sizes of one and "zero inventory" is never really achieved, the aim is to move towards these via incremental improvements. At each step, problems are solved as they are revealed so that further reductions in lot size and inventory can take place. Both activities have implications for action at the workstation, elsewhere in the production process, and in other parts of the firm.

(a) Instituting lot size reduction is a straightforward management decision. However, to achieve it demands a quick-change capability that has many implications for workforce training, machine maintenance, and engineering functions. At the same time, this flexibility and changeover capability give product designers and marketing people new opportunities and freedom of action.

(b) Reduction of workstation and buffer inventories is a management decision that also requires comprehensive attention to quality, a major change in relations with suppliers, including improvement in their delivery, and a system for managing the in-house delivery of parts on demand. The most widely discussed and probably least understood of the needed steps to facilitate this is the so-called kanban system of inventory control.

3.28 Kanban is simply a method for parts ordering. A card or chit (the kanban) travels with a container of parts or sub-assemblies. When the container is empty and the last part/sub-assembly is used, the card returns to the part/sub-assembly supplier where it becomes a document authorizing the production and release of another batch of parts/sub-assemblies. The objective in managing a kanban system is to minimize the number of containers/cards in transit, those waiting to be worked on, and those waiting to be filled.[109/]

3.29 However, various steps need to be taken before a company can operate kanban effectively. These involve cutting lot sizes through reduced

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109/ Kanban can be operated on a paper basis and does not need computers. Toyota's Kamigo engine plant, which produces 250,000 units a year and is widely reputed to be the most efficient plant in the world, operates entirely on a paper-based kanban system. American plants, which are three times larger, with six times more material inventory, use six times more labor per engine than at Kamigo.

engineering set-up time, streamlining plant configuration, and introducing a sound TQC program to minimize quality-related delays, stoppage, rework, and lead times. Although kanban systems only work under JIT conditions, JIT can work on the basis of other pull-through inventory control techniques. There are many variations of kanban systems suitable for different types of firms and products.[110/] Most important, contrary to the common impression given in the literature, kanban is only one aspect of the new practices. For most companies it is the last part of the production process, put in place after all other steps have been taken.

3.30 When combined with lot and inventory reduction, workflow reorganization generates numerous benefits. Based on experiences of small- to medium-sized U.S. engineering firms, three of these appear potentially significant from the perspective of developing countries.

3.31 Line reorganization often reduces the physical space required for production and can generate substantial savings in unit fixed capital costs, particularly when new plants use JIT principles.[111/] For instance, Fort Motor Company wanted to build a new power train plant in the early 1980s. It received bids from American and Japanese companies for the same plant, same product, same output level. The Japanese bid pegged construction costs at US$100 million compared to US$300 million for the U.S. design, with total space at 300,000 sq. ft. compared to 900,000 sq. ft. The differences were due to the use of simpler, cheaper machines and the virtual absence of material handling devices (carts, conveyor belts) and inventory storage. Savings on a similar scale would be attractive for planners and financiers of investment projects in developing countries.

110/ For instance, some assembly lines can operate with kanban "squares." These are squares marked out on the work tables at each assembly point. After a line worker has finished his assembly task, he places the workpiece in the kanban square at the adjacent station and, in turn, expects to find another workpiece in his own square, just passed on from the previous station. If the square is empty when he is ready to assemble, or if he cannot keep the next kanban square filled as needed, this is a sign that there are problems.

111/ Inductoheat, a typical mid-sized job-shop producer of heating equipment, decided to adopt some JIT practices in 1982. Workplace reorganization entailed five points: remove everything unnecessary, not just inventory; create a place for everything; and pursue cleanliness, discipline, and participation. One major aim was visibility, so that non-performance would be obvious in the normal work pattern. Another was to increase frequency of part delivery. Simplifying work practices along these lines in the first month eliminated five trailer loads of excess material, equipment, tooling, and trash. Sales in 1986 were 3.6 times those in 1981; return on equity at 28% compared to -2% in 1982; inventory 50% less than five years ago; workturns up 400%; floor space halved, and employment reduced by 20% (Williams, 1986).

3.32 The second benefit of workflow reorganization relates to the simplification of production planning activities made possible by line reorganization. In large multiproduct firms, the planning process for clustered production can be complicated since many different parts, operations, and production routes are involved. This planning effort is information-intensive, requiring either a lot of paper or sophisticated computer-based systems, and a great many indirect personnel who monitor work flow in the factory (schedulers, dispatchers, stock takers, expediters, inventory clerks, and specialist data processors).

3.33 The new practices eliminate much of the need for this complicated planning apparatus (and its supporting hardware, software, and staff)--including elaborate and expensive computer-based planning systems. Simplification of the production planning process via reorganization could be particularly important for developing country enterprises where X-inefficiencies account for low productivity.

3.34 A final benefit significant for developing countries is that continually reducing lot size and overcoming other obstacles to the smooth flow of production results in considerable reductions in lead time. Lead times are included in all aspects of production: production set-up, filling orders, responding to customer requests for quotes and specification, producing designs and proto-types, and in getting new products to market.[112/]

3.35 As a result of marketplace demands in recent years for quick turnaround and rapid response to shifts in demand, lead-time factors have become critical determinants of competitive success. Consequently, lead-time reduction via the new practices is seen as one of the key dimensions of competitiveness where Western manufacturers can effectively fight back against both their Japanese and developing country competitors. This aspect has direct implications for developing countries, which we take up in the last chapter.

3.36 Reorganizing job-shop production along flow lines (and introducing lot-size and inventory reductions) is a complicated process that can be done only in stages and often over a long period. Achieving flow-line production requires the gradual introduction of a variety of other practices that affect the management of the workforce, relations with suppliers, quality of goods,

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112/ Plants can reduce lead times only by solving problems that cause delays. Such problems run the gamut of plant/firm operations: order-entry delays and errors, wrong specifications, long setup times and large lots, high defect counts, machines that break down, operators who are not well trained, supervisors who do not coordinate schedules, suppliers that are not dependable, long waits for inspectors or repair people, long transport distances, multiple handling steps, and stock record inaccuracies. All of these obstacles are likely to receive intense focus from the new practices.

as well as operation of machinery.[113/] The scale of the changes required can be daunting to managers of sophisticted multi-product, multi-stage plants in the industrialized countries. Because of this, it is unexpected but not surprising that practitioners universally acknowledge that reorganization is perhaps suited to light assembly and job-shop engineering firms (both of which are found in great numbers in developing countries) than to the mass production of complicated final products such as automobiles.[114/]

3.37 Eliminating variability via simple measurement and observation. After line reorganization, the business of process management shifts to the system itself and the identification and correction of problems of variability. The aim is to move all systems toward constant performance within acceptable standards. Identifying performance variations and quality defects and tracking down their causes are not accomplished by ad hoc observation and hunches. Hence, great emphasis is placed on the importance of rigorously collecting, analyzing, and using data on the production process to identify and solve quality problems.[115/]

3.38 Various techniques for the collection and analysis of reliable, accurate information on system performance have been developed and are described in detail in a number of texts. Among widely used quality-control techniques are a set of process control measures involving both quantitative and qualitative data. The best known of these is Statistical Process Control (SPC), which is a simple technique for measuring deviation from the mean for different quality parameters. There are other techniques, shown graphically in Figure 3.5 and described at length in all the practitioners' texts.[116/]

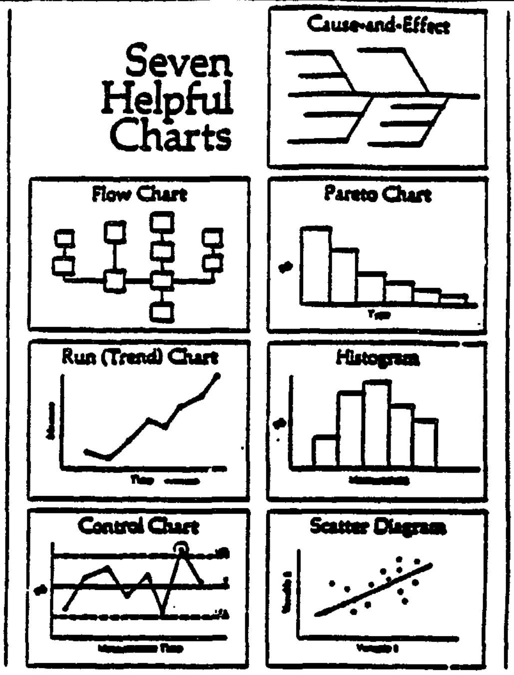
113/ Practitioners propose a number of techniques for accommodating the principles to the reality of firm, products, and layout-specific conditions, and for making the transition. See Schonberger (1982).

114/ See Schonberger (1986), Chapter 6.

115/ From a training manual put out by Komatsu, Ltd. of Japan, a company that nearly singlehandedly destroyed American tractor companies, such as Caterpillar and is a major supplier of tractors to developing countries: "The first step in quality control is to judge and act on the basis of facts. Facts are data such as length, time, fraction defective and sales amounts. Views not backed by data are more likely to include personal opinions, exaggeration and mistaken impressions. Data volume has nothing to do with the accuracy of judgment. Data without context, or incorrect data, are not only invalid but sometimes harmful... It is necessary to know the nature of that data and that proper data be picked as well." (cited in Walton, 1986).

116/ See also Crosby (1979); Feigenbaum (1961); Ishikawa (1972); and Shingo (1985).

Figure 3.5 Quality Control Charts Designed for Use on Shop Floor



Source: Walton (1986), p. 98

3.39 One significant characteristic of these techniques is that they are intended primarily for use by the production workers who are responsible for collecting the data and information needed to prepare them. There are some, of course, such as run and control charts that require simple statistical training to prepare. However, most of the expertise in using these techniques to improve quality and performance lies with workers and line supervisors.[117/]

3.40 These techniques, combined with the worker's understanding and commitment to quality (for which he should also be paid), transform the production workforce into quality-control experts. Enormous improvements in quality and reductions in quality-related costs translate directly into improved market performance and greater profitability. However, these techniques are tools only, not the source of quality. They will be of little use unless management creates conditions in which quality is seen by all as the key to success.

117/ A common theme among practitioners is that quality control charts should be on full display in the relevant work area. The objectives of making shop performance data "public" are threefold: (a) everyone becomes aware of the quality- control effort and what needs to be done to improve performance; (b) valuable information is available so that everyone can learn from it; and (c) customers may request to see or inspect the evidence of a firm's quality performance.

Managing Supplier Relations

3.41 The new approach to organization calls for profound changes in the relationship between suppliers and their customers.[118] In the old system, suppliers and customers formed an arms-length or adversarial relationship. The main criterion of supplier selection was price. Quality, delivery time, and technology were secondary factors. Buyers multi-sourced component purchases to provoke competition, which would drive down the price and reduce their risks of supply disruption. Contracts were short-term and frequently shifted from supplier to supplier because of fractional price reductions. There was no exchange of design or production information--on the contrary, outright hostility occurred if either party expressed the desire for such information. Finally, suppliers' plants were located at a distance from customers because suppliers were not tied to one customer.

3.42 Currently, all aspects of the above situation are changing. In an environment in which JIT organization ultimately will become paramount, and with growing complexity in technology and rapid product change, the old buyer-supplier relationship is becoming anachronistic. Plants have to be better located to allow JIT delivery. Suppliers must be highly flexible. Design secrets have to be shared, and buyers and suppliers must develop new modes of cooperation. Most important of all, quality and reliability have become the key determinants of supplier selection. Achieving these changes is not easy, with much mistrust to be overcome on both sides.

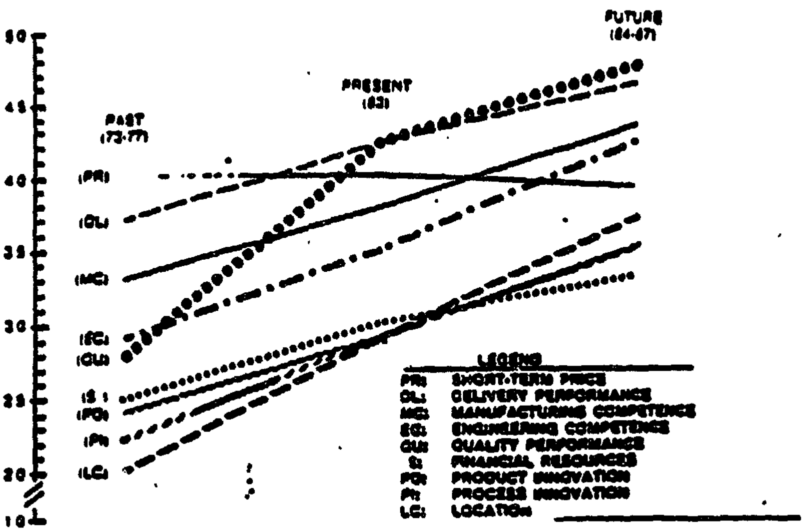
3.43 Suppliers are having these new buyer requirements imposed upon them while also having to introduce most of the intra-firm organizational changes (discussed above) to meet the new performance criteria. As with intra-firm practices, the new supplier relations are characterized by a number of features. Four of these are particularly important:

3.44 (i) Quality. The most significant change is the growing importance being given by buyers to component quality, i.e., its perfection and consistency. Figure 3.6, based on a survey of the U.S. auto component industry, shows clearly how quality has now become the single most important determinant for supplier selection, while consideration of price has declined considerably. The same phenomenon is occurring in other engineering product groups.[119]

118/ Hoffman and Kaplinsky (1988).

119/ See Morgan (1986).

Figure 3.6 Trends in Perceived Assembler Criteria for Selecting Suppliers
(1 - not important; 5 - extremely important)



Source: Hoffman and Kaplinsky (1988)

3.45 A key dimension of the shift to quality is that contract (i.e., entry) standards are now much higher: if component quality is not up to the stricter buyer standards, suppliers are not allowed to bid on the contract. Another dimension is that the quality of the product must not only remain consistently high but also improve over time. In Japan, providing quality is seen as the joint responsibility of the buyer and supplier. Buyers typically provide technical support to suppliers to upgrade their quality; this has proved to be enormously important in helping suppliers make improvements, and buyers frequently visit suppliers' plants to make sure quality procedures are followed. This close interaction has been more difficult for U.S. and European suppliers to accept but is now becoming common.

3.46 (ii) New contractual relations. The contrast between Japanese and U.S./European buyer-supplier relations is probably strongest in the area of contractual relations. In Japan, contracts are agreed to and implemented in an atmosphere of mutual trust. In the U.S. and Europe, contractual relations are habitually conflict laden, although fundamental change is beginning to occur, principally in two areas: a shift to "single sourcing" whereby a buyer uses only one supplier to provide a component; and the replacement of single-year contracts by multi-year contracts. These contracts are for much larger quantities than previously ordered, giving the winning supplier the advantages of scale and stability that frequently have been absent. The buyer gains in quality costs and reliability. The new contracts require a whole new relationship between the two sides, featuring much closer interaction on design and in production scheduling.

3.47 (iii) Changes in the design relationship. Another area where change is occurring is the suppliers' role in the design and development process. Traditionally, buyers provided the design work and specifications for suppliers to bid and build on. This is now changing. First, with new emphasis on the quality of the component, the quality of the specification must increase considerably as well. Because variability in component quality can no longer be tolerated, the precision of specifications is receiving a great deal of attention.

3.48 Second, suppliers now are expected to take a much larger role in the design process for components and to do much of the design work previously carried out and provided by the buyers. Third, the nature of components is changing. Instead of their being provided individually to the buyer for assembly into sub-assemblies and final products, components are becoming part of the modularization of component systems. This means, for instance, that cars are designed in terms of systems--wheels and brakes, seats, the interior "cockpit," door/window systems--which suppliers are expected to design, build, and provide pre-assembled to the buyer. These modular components are ready to be "plugged" into the car on an "as-needed" basis. Needless to say, new technologies, particularly electronics and new materials, are important here.[120/] The implications of these trends for developing countries as input suppliers are profound and are discussed in the last chapter.

3.49 (iv) JIT delivery and location. The geographical demands of the new system constitute perhaps the most visible change in supplier relations. JIT delivery requires physical proximity between supplier and assembler. Japanese performance in the area of JIT delivery is the ideal.[121/] The JIT delivery system requires organizational change first and is easily managed on paper, as Toyota does, but once established, the use of computers is a logical extension. The move to JIT delivery and proximate location of suppliers to assemblers is not as far advanced in the U.S. and Europe, yet the trend is unmistakable: as with quality, the ability of suppliers to deliver JIT is becoming a key criterion for supplier selection. Table 3.3 shows that U.S. auto component suppliers are moving towards JIT and proximate location. Although less empirical data is available on developments in other industries, the trend is expected to spread.[122/]

3.50 All four areas reviewed have important implications for future LDC prospects. We turn to these in the final chapter.

120/ Hoffman and Kaplinsky (1987).

121/ Typically in a Japanese plant, a large share of parts will be delivered at least on a daily basis and sometimes more frequently.

122/ Morgan (1986) and Hoffman and Kaplinsky (1987).

CHAPTER IV

CONCLUSION

Summary of the Issues

4.01 The technological and organizational transformation of the engineering sector has been the primary focus of the preceding chapters. In Chapter I, we argued that the focus of the innovation process was irrevocably shifting from "islands" of automation towards the systemic integration of the production, design and control spheres. Ultimately this means highly integrated CIM facilities will become commonplace.

4.02 For the foreseeable future, the technological locus of the competitive struggle in the engineering sector lies in the development and of integrated, flexible systems within individual spheres and particularly within the production sphere. The same movement towards greater integration is occurring in the design and management spheres. The route towards their integration within the firm is now well defined--although difficult to pursue.

4.03 Three aspects of this shift towards flexible integration are important. First, flexible systems enjoy considerable economic advantages over lines employing stand-alone automation technologies--a gap that opens even wider against production relying on conventional metalworking technology. Second, the key to efficient use of flexible systems lies in a firm's own flexibility in the management and organization of production. The effective use of these systems demands the functional and vertical integration of previously separate responsibilities, coupled with a sharp increase in the engineering intensity of design and production. Simply put, integrated technologies work most effectively in integrated organizations featuring a highly technically competent workforce.

4.04 Third, and most important, a sizable share of the gains from investment in flexible technology comes from organizational change. This suggests that organizational innovation is in fact separable from technical change--and frequently eliminates the need for more complex systems of hardware. Calls for fundamental change in production organization and managerial attitudes have become a central theme in much of the analytical and prescriptive literature on industrial development in the advanced economies.

4.05 This growing emphasis on the importance of organizational innovation separate and independent from the previously dominant preoccupation with embodied technological change, is the most significant, albeit counterintuitive, finding of this research. The analysis and discussion in Chapters II and III explored these developments further to illuminate the scale and pattern of diffusion of organizational innovation at the sectoral level and the nature of the changes occurring at firm level.

4.06 This review demonstrated that the new organizational practices have moved outward from the motor vehicles sector in Japan and across national and sectoral boundaries. After a period of skepticism and misunderstanding, management in the U.S. and Europe is increasingly aware that the introduction of the new practices, independent of any technology-related activities, can generate substantial and sustainable gains in productivity, quality, market share and profitability.

4.07 Awareness of the need for change, and understanding of how to go about it, are no longer confined to a few leading-edge firms, business school professors, and messianic management consultants. The message is echoing in the halls of government, in boardrooms, in the business schools and in the media. Consequently, we feel the degree of attention paid to organizational issues in this paper is justified, because of their intrinsic importance and because of the role they play as precursor and facilitator for the more widely recognized changes coming from industrial application of information technology.

4.08 A New Industrial Paradigm? One of the broad hypotheses underlying our analysis is that flexible automation technology and organizational innovations are coalescing into a new best-practice manufacturing system now diffusing throughout industry. We would argue that in the course of this diffusion process, the determinants of international competitiveness are being changed and the rules governing the hierarchy of economies and industries are being rewritten. The engineering sector, in its widest sense, is acting as midwife to the birth and early development of what many other observers have called a new industrial paradigm.

4.09 Obviously the "evidence" presented in Chapters I and II does not constitute a sufficiently comprehensive and statistically robust sample to "prove" the existence and diffusion of this new paradigm within the industrialized countries. Nor are the technological and organizational elements of this new best-practice manufacturing system likely to be fixed or immutable. Situation-specific conditions, the retarding weight of costly sunk investment in existing technology, decades of confrontational labor-management and supplier-producer relations, and the "tunnel vision" of U.S. and European managers inevitably will interact with the principles of each element. The end result will vary widely--from outright rejection to differing adaptations, with different elements spreading unevenly and piecemeal across firms, sectors and countries.[123]

Assessing the Implications for Developing Countries

4.10 These qualifications suggest that any attempt to predict the speed, pattern and extent of adoption of this new best-practice system across countries and sectors would be of little lasting value. Nevertheless, we believe the documented processes of technological and organizational change are powerfully indicative of the dominant trends now manifest in the global manufacturing sector. These changes broadly define the parameters that will

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123/ Piore and Sable (1984) argue this point well.

characterize the structure of manufacturing enterprises in engineering and across many sectors. And since these changes will likely be major determinants of international and national competitiveness, firms and policymakers in the developing countries will have to confront the implications.

4.11 This is not an easy task since it is still difficult to define precisely what the implications will be. Although some aspects of IT-related developments are affecting a small band of countries, the implications of flexible manufacturing technologies and the new practices are at best only generally discernible for most economies. This degree of uncertainty about the future, coupled with an inadequate knowledge base, suggests rather mundanely that the initial response of policymakers should be to become well-informed about international trends and aware of the constraints inhibiting their manoeuvering in particular situations.124/

4.12 Unfortunately, the available empirical literature concerned with IT and developing countries is of limited use in evaluating the implications of the new paradigm for the Third World and the actions open to policymakers, for two reasons. First, country coverage in relation to the engineering sector has been confined largely to trade-related questions of immediate importance to a handful of countries. Second, the focus of this literature has been, with one or two recent exceptions, almost entirely on developments arising from the diffusion of stand-alone automation techniques and not on the forms of technological and organizational change reviewed in this paper.

4.13 However, it is possible to consider the impact and implications for the Third World at two levels: first, as issues arising from the manner in which the technological and organizational developments may affect developing countries' capacity to respond both internationally and domestically. Second, by focusing more narrowly on the issues that concerned us in Chapters II and III--the problems and possibilities for the introduction of the new organizational practices within the Third World.

Implications for the International and National Competitive Context

4.14 The uneven diffusion of flexible manufacturing technology and organizational change will remain for many years an important feature of international trade and competition. A major feature of the diffusion process will be the continued rapid spread of stand-alone automation technologies in the industrialized countries and their less rapid spread in the developing countries. As noted previously, there was an early (and continuing) warning in the literature that differing rates of North-South diffusion would undermine the low-wage advantage of Third World manufacturer/exporters and generate

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124/ Though lack of comprehensive up-to-date knowledge is a problem confronting Third World policymakers in all areas, it is particularly problematic in relation to those fields where information technology is having an impact--both because developments in the industrialized countries are moving quickly and because so much information reaching developing countries on these topics is not accurate.

unfavorable employment and welfare effects in developing countries.125/ Given the prior extensive treatment of these issues elsewhere, we wish to make only three sets of points on this topic.

4.15 First, the most recent reviews of developing country use of stand-alone automation suggest that at least until the mid-1980s, even the leading-edge countries, the NICs, were still some way behind the advanced industrialized countries. This comes out clearly in Jacobsson and Edquist's (1988) comparison of relative stocks and rates of diffusion between the NICs and the OECD countries.

4.16 In 1985 Korea had the most NC tools of all developing countries, with 2,700 units, while Japan alone had 120,000; by 1985 the NICs had approximately 400 robots in use while there were more than 100,000 in the OECD countries. In terms of CAD use, in 1985 the U.S., West Germany, Japan, the U.K. and Sweden had more than 90,000 "seats" while the NICs had 2,100. By introducing a scale-related factor into these comparisons (the density of use per engineering sector employee), the figures show that the OECD countries had 8.5 times as many NCMTs as the NICs; 8.3 times as many CAD systems; and 43 times as many robots.

4.17 Comparing rates of diffusion is more difficult. It appears that as of the mid-1980s the rate of diffusion of NCMTs in the NICs was not sufficient to "catch up" with the industrialized countries, primarily because the share of new investment allocated to these techniques in much lower in the NICs--7%-23% as against 40%-62% for the OECD countries. Available information on the rates of diffusion for robots and CAD systems is confusing: although most are well below OECD levels, a few countries such as Singapore show high rates of use, possibly on a par with developed countries.

4.18 Second, despite this apparent widening of the technology gap, and a good deal of well informed speculation 126/ there is little hard evidence that the use of stand-alone automation in the engineering sector in the advanced countries has resulted in a substantial loss of export markets for developing countries, or in the relocation of offshore facilities established by Western producers. This may change as the level of technology integration

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125/ The literature unfortunately has failed to reconcile the rather contradictory nature of these two positions. Presumably an economy could suffer both the loss of competitive advantage due to non-adoption of new technologies in one sector and the loss of jobs due to widespread adoption in another. However, both these arguments are so often stated in the literature by different analysts in such uncompromisingly, all-encompassing terms (reminiscent of the dependency arguments) that any other outcome is ruled out!

126/ Jacobsson and Edquist (1988) make the most rigorous attempt in the literature to assess this question by reviewing the relative rates of penetration of automation techniques into sectors where NIC exports are concentrated, and show that the threat to the NICs' competitive advantage, though real, still lies in the distant future.

rises among Western users, but we suspect the initial fears were overstated and based on an assumption that stand-alone automation techniques were much more competitive against earlier electromechanical versions and low wages in developing countries than was actually the case.127/

4.19 Indeed, the most significant threat to competitive advantage in the engineering sector for the less developed countries has come not from process innovation but from product innovation in the machine tool sector. The growing strength of the NICs as exporters of simple tools such as lathes is being challenged severely by the growing design intensity of the product (due primarily to use of CNC units), associated increases in minimum scale economies, and the rise of Japan as a major competitor.128/ To maintain export markets in developed, and increasingly in developing countries, a switch will have to be made to the design and production of CNC tools. The same logic probably applies to other machinery segments of the engineering sector where the new product technology is making inroads, but this assumption needs to be examined empirically.

4.20 For the many countries still far removed from the technological frontier in machine building and exporting, the penetration of NC, CNC and programmable controllers into machine design poses major new technological obstacles to their (admittedly remote) prospects for entering the international market. However, empirical research has shown that some NIC firms are succeeding in making the transition to export of microelectronic-controlled machines--and that many more firms are producing these for the domestic market. 129/

4.21 The NIC experience suggests that government policy is extremely important in supporting firms' learning process and attaining minimum scale economies while assimilating the new product technology with an eye towards exporting.130/

4.22 More fundamentally, NIC firms exporting NC machines were already competent machine builders before mastering the new product technology. Without that prior experience, the task would have been inestimably more difficult. This underlines the obvious, but often ignored, point that the export aspirations of non-NIC countries in the machinery (and broader en-

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127/ See Hoffman and Rush (1980), Jacobsson and Sigurdson (1983), Rada (1982) and Kaplinsky (1982), for the early arguments; the articles and references contained in Hoffman (1985) for a review of the first round of empirical evidence and James (1987) for the most comprehensive listing of references on this topic and a rather sanguine review of the literature.

128/ See Jacobsson (1985).

129/ Kim (1986) reports that 110 large and small firms are engaged in machine tool production in Korea. Production of NC tools has increased from only $200,000 in 1977 to over $38 million in 1985.

130/ Jacobsson (1985) and Franzman (1984, 1986).

gineering) sectors are constrained on the technical side not by their lack of IT skills but because of the pervasive weakness in their basic mechanical engineering and machine design and building capabilities--coupled with structural problems that are often policy-induced.[131] If such countries can overcome these obstacles to the point where the export of conventional machines is a viable proposition, then the success of NIC producers suggests that moving into the microelectronics era may not be as great a hurdle for the less advanced countries as most observers assume.

4.23 Our third point is a simple one and follows this line of argument but in relation to the largely pessimistic view in the literature about the prospects and impact of the use of stand-alone automation technologies in developing countries. All the available evidence (relating primarily to limited NIC use of NCMT) indicates that if developing country firms are already efficient users of conventional techniques, they will face few insurmountable technical or skill-related problems in using NCMTs or other stand-alone automation techniques--though capital costs, scale requirements, available skills, protected markets, and the availability of supplier support will act as constraints.[132]

131/ This is hardly a new argument in the technology and development literature, but it does seem to have been largely forgotten by those concerned with the impact of automation on the Third World.

132/ For the NICS and nearly-NICS, these problems are not insignificant, but most are amenable to government intervention. A variety of mechanisms for overcoming knowledge and skill constraints are available. In general, the most important in the longer term are attempts to overcome the skill constraint. Universities and technical institutions, as well as in-firm training programs, must reorient their curricula away from conventional skills and towards skills relevant to the use of the new techniques--NC tool operation, maintenance and programming; and for engineers, the use of CAD systems in basic and detailed design, etc.
The knowledge constraint can be attacked more directly by providing potential information about the uses and benefits of the new technology to potential users, by seminars, workshops, exhibitions, "showcase firms," national information centers, etc. At the same time, the local service industry must be strengthened, particularly in software support, such as maintenance and product upgrades, areas where foreign suppliers tend to be weak. In relation to hardware, although import restrictions are a tool for supporting development of local production capacity, these must be eased in, to ensure that local users gain access to a wide array of techniques--consistent with development of a competitive local supply industry. See Jacobsson and Edquist (1988) for a more detailed discussion; see ʾlso Chudnovsky (1986) for a discussion of the experience of Argentina, and James (1987) for a review of Third World use of the new technology.
See Chudnovsky (1986) for a discussion of the experience of Argentina, and James (1987) for a review of Third World use of new technology.

4.24 The problem, of course, is that many Third World engineering firms are not efficient users (or improvers) of conventional techniques. This suggests that the macro and micro causes of the inefficient use of existing techniques must be tackled as a prerequisite to the introduction of stand-alone automation. If this were to happen on a broad scale, the early concerns about the use and impact of stand-alone automation take on a different perspective: these techniques will be introduced into a dynamic context where firm and sectoral productivity, output and employment are rising rather than remaining static or falling, as in many countries today.

4.25 Arguments based on X-efficiency grounds often attribute performance differences between North and South enterprises in machine-level productivity (often surprisingly close) versus overall firm productivity (almost always much lower in developing countries) to organizational deficiencies resulting from incompetent management. Recent literature on questions of indigenous technical change and the mastery and absorption of imported technology adopts a similar though less explicit perspective.

Problems and Possibilities for Organizational Innovation in Developing Countries

4.26 Before exploring these issues, we need to make one qualification about the discussion that follows. Since there has been virtually no debate about these issues in the literature, our observations on the prospects for introducing organizational change in developing countries are offered as a means of provoking further discussion rather than as definitive conclusions. In this regard, we should make clear we do not intend to address the specific policy implications of organizational change, as this would be far too premature without comprehensive analysis and evidence.

The Problems Considered

4.27 In the course of reviewing the literature and preparing this paper, it was impossible not to compile a list of reasons why introduction of the new organizational practices would face serious obstacles in the Third World. Two sets of "first-order" factors seem most problematic.

4.28 (i) Skills constraints on the capacity for change. The first set is related to the issue of skill level and the overall competence of management, engineers and production workers in Third World firms. The successful introduction of the new practices requires both a minimum number of well-trained people (managers, staff and line workers) compared to the total workforce, and a minimum degree of competence in their areas of specialization--including, of course, a willingness to change attitudes and embrace the new practices.

4.29 For most Third World firms, critical shortfalls occur in management and engineering. All the problems Western managers, engineers and workers face in adapting to the new practices not only would exist in a Third World context but could be greatly compounded by lower levels of skill and education and by cultural, religious, and racial prejudices that would inhibit the establishment of working relations based on cooperation and mutual trust.

4.30 Long-standing management problems in the Third World are widely acknowledged in the literature as a prime cause of poor industrial performance.[133/] Such analyses undoubtedly have merit, but they fail to see that poor performance may result from the pursuit of totally inappropriate management practices.[134/] Yet the logic of the new practices suggests that Third World firms will face problems not just because of poor managers but also because of their fundamentally flawed management approach. [135/]

4.31 Much the same points can be made about the obstacles posed by the engineering intensity of production under the new practices. The problem caused by severe skills shortages will be compounded by poor deployment of engineers and by attitudinal and cultural problems limiting their usefulness. In most developing countries, engineers are white-collar and managerial, whereas engineers in the new practices are constantly involved in solving problems on the shopfloor in support of production workers.[136/]

4.32 These same issues crop up if we consider the implications for the introduction and use by developing countries of more flexible integrated systems such as FMS. We can deal with this issue very briefly. There are

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133/ See Kubr and Wallace (1984) for a review.

134/ A typical example of this is Gershenberg (1987), a useful research report concerned with the role of foreign versus local firms in the spread of managerial know-how in Kenya. Unfortunately, the analysis is carried out without once specifying the type of management practices involved.

135/ Thus, even if the managers have all been sent abroad to prestigious business schools and got straight As, problems still lie ahead since to be effective with the new practices they will have to dislearn everything they learned in school! Schonberger (1982) sums this conundrum up well.

> "Unfortunately, masses of (developing country) people (have been) attending Western colleges so that they may return to their countries and help build an industrial base...They may learn too much about too little and go home to become experts in risk management or automated storage retrieval, settling into lifetime careers as they see their Western role models doing...In this scenario, the best minds in the country will be wasted working out complicated solutions to narrow problems. One wonders how the plants they build and operate will ever be competitive in world markets." (p. 210) (FTNT Deming quote)

136/ The problem of the underemployment and misdirected deployment of Third World engineers in jobs that have nothing to do with production is well-documented (see Teitel, 1987 and Hill, 1987). This problem is compounded by the fact that those who do actually work inside enterprises are, like their western counterparts, loathe to get their 'fingers dirty' by getting too intimately involved with the solution of shopfloor problems. Schonberger, 1982 cites some examples of this.

grounds for arguing that flexible systems, because of their lower scale economies, might be well suited to the limited market conditions typical of many developing countries. Equally, one could argue that the capital costs and greater complexity of these systems work strongly against their introduction in all but the most advanced segments of the NICs. These alterative positions provide a speculative standoff because there are few, if any, truly flexible systems in place in developing countries to demonstrate empirical support.

4.33 Much more pertinent are the points made in Chapters II and III. There is little sense in a firm's attempting to introduce flexible systems unless its existing processes have been thoroughly restructured according to the principles of "simplify, combine and eliminate." A firm must already have taken steps to introduce greater functional and vertical integration as well. For obvious reasons, the need to make these changes as a precursor to FMS would be much greater in most third world enterprises. Add to this the evidence that the successful introduction of the new organizational practices yields commensurably greater gains than the use of new technology. Taken together, these points comprise a powerful a priori argument that developing country enterprises should be vigorously pursuing the new paths of organizational innovation rather than making high cost and high risk investments in new technology--whether stand-alone or integrated.

4.34 The literature has always been concerned about the social and private costs of low levels of engineering skill and limited learning opportunities.[137] The Japanese experience (where engineering-intensive production leads to consistent productivity increases) shows that the opportunity costs of this situation are, if anything, much higher than previously thought.

4.35 Two additional factors compound the obvious problems posed by the endemic shortage (and poor quality) of production skills--for draftsmen, welders, fitters, foundry and heat treatment workers, machine tool operators, tool and die makers, etc. First, educational levels for workers are very low, thus increasing the difficulty of the retraining and upgrading task. Second, in-firm training programs are non-existent or inadequate. Severe shortages of skilled production workers are, in effect, a creation of underdevelopment itself and of the lack of an industrial tradition in many Third World nations.

4.36 (ii) Constraints on the scope of change. The second set of constraining factors limits the scope for firm-level change. Some of these are internal to the firm. For instance, both financial and size limitations will reduce a firm's ability to absorb the costs and dislocations of organizational change. Resource constraints inhibit raw material purchases, leading to low output. Typically, Third World engineering firms have a limited capacity to develop new products, absorb new technology (particularly product know-how) and open up new markets. This limits their product mix, constrains

137/ See Bell, Ross-Larson and Westphal (1985); Dahlman and Westphal (1983).

their growth potential, makes them vulnerable to market fluctuations, and makes the internal environment less conducive to change.[138/]

4.37 External constraints are probably even more severe. The most obvious are those imposed by market factors, such as small size and fragmented structure. In recent years, recessions have crippled firms' capacity to transform themselves. Other, market-related problems also can distort or inhibit responses--the low price of labor, poor consumer response to quality and service, the price elasticity of demand, the import intensity of existing producers, and the various factors (legislated and otherwise) that lead customers to prefer imports over local products.[139/]

4.38 Other problems are imposed by industry structure, for example, the distorting effect of foreign firms' dominance. The poorly developed network of subcontractors and suppliers of specialized services forces many engineering firms to perform tasks in-house that might more efficiently be subcontracted out, or in the case of special services, to do without completely. Another problem, greatly exacerbated by foreign exchange shortages, is the lack of uniform and reliable raw material supplies.

4.39 Of course, government macro-economic and industrial policies often play a major role in determining the nature and existence of many of these external constraints. In one sense, the problems from government intervention are similar to those that inhibit firm-level innovative behavior in general, in that they effectively restrain the disciplinary character of the market and its ability to reward performance with increased profits and market share.

4.40 The range of policy-induced problems is wide and well known--excessive and incompetent state involvement in production; overvalued exchange rates and artificially low producer prices; a grossly distorted price system; excessive import protection; capacity licensing policies; and legislated barriers to entry and exit that encourage suboptimal levels of concentration and competition.

4.41 The debate over the merits of free-versus-controlled markets and over the appropriate forms of government intervention (posing a choice between a free market versus state-dominated economy) misrepresents the problem faced by many developing countries. The choice is between efficiency and inefficiency, competence and incompetence, and the costs of state monopoly versus the benefits of dynamic and innovative performance by a firm. These conditions can exist under open market conditions or in situations of state intervention.

4.42 The twin tasks of how to reform the market to provide incentives for firms to be efficient and to invest in organizational change (and other types of innovative effort) and how to devise benign interventions to assist

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138/ See UNCTAD (1985) for a review.

139/ Similar distortions arise in the case of labor markets, where the low price of labor would inhibit management from paying higher wages to attract more skilled staff and production workers.

this process are difficult policy problems, aggravated by the present contentious climate regarding the issue of state intervention in the economy. These qualifications are a reminder of the need for caution in drawing conclusions about the issues raised in this paper. However, they also tell only one side of the story, and we need to balance our assessment of the problems against the very significant possibilities to which we now turn our attention.

The Possibilities Considered

4.43 Four aspects of the new practices provide strong a priori grounds for our hypothesis concerning their applicability in developing countries. First, as the discussion in Chapters II and III has brought out, most new practices are neither scale, product, sector nor function-specific. The pursuit of goals such as "eliminating fear from the workplace," breaking down barriers among staff, and instilling a concern for quality are well within the province of management anywhere.

4.44 The same is true with most of the techniques associated with preventive maintenance, production line reorganization, management of machines, upgrading of worker skill and responsibility, use of shopfloor quality control measures, new forms of supplier relations, etc.140/ They are all suitable for use in most types and scale of discrete product manufacturing. The obstacles to the introduction of the new practices in less developed countries may well lie elsewhere, but they are not to be found in the realm of scale and product

140/ Of course, the most well-publicized elements of the new practices like kanban inventory control are best suited for a mass production situation since that is what they were designed for. Gains accruing strictly to inventory reduction in Western firms carry much less weight in Third World conditions of low capacity utilization.

However, this observation misses the point that the greatest gains from inventory reduction come from the "reduction of waste" arising from the exposure (and correction) of the variety of costly production problems related to quality, treatment of machines, poorly trained workers, the way production is organized, etc., reviewed in Chapter III. Such problems surely exist in all Third World engineering plants and considerable gain would accrue from their elimination. If there are no inventories to reduce (or if the scale of operations is smaller), this makes the task of problem exposure and solution and production "control" easier not more difficult!

characteristics or in the type of tasks carried out.[141] The problems tackled by organizational change are faced by all developing country engineering firms (indeed, in most less developed countries' manufacturing and service enterprises), regardless of their technological competence, size, product mix, or market orientation.

4.45 Second, there is no mystery behind how these practices work. Indeed there are numerous "how-to" books that describe practically how firms should go about introducing the new practices. Moreover, most management consulting firms provide specific advice on the practices (e.g. through seminars). In short, the new practices are codifiable and accessible.

4.46 Third, though we cannot provide precise figures, it seems logical that the capital cost (and foreign exchange cost) involved in introducing the new practices will be relatively low--certainly much lower than the costs involved in introducing new technology. Low cost is accompanied by low risk--particularly considering that it is possible and, indeed, advisable to introduce these practices on a step-by-step basis, only moving as fast as the absorptive capacity of the people and sector involved.

4.47 Finally, although many types of firms face difficulties in introducing the new practices, the heterogenous nature of the engineering sector means that many firms in that sector stand a good chance for successful organizational change.

4.48 Conduits for change. Among the best candidates would be subsidiaries of foreign firms (Western and Japanese) that have already introduced, or are pursuing, organizational change in their home locations. Many of these firms are well represented in particular segments of the engineering sector in developing countries--and would have sufficient technological, financial, and managerial resources to pursue organizational change. A few have started to introduce these practices in their overseas subsidiaries (such as some auto assemblers and component firms in Brazil, India and Mexico).[142]

141/ Indeed we can draw attention here to a related point made by the practitioners and mentioned earlier, that techniques such as production line reorganization are in fact much better suited to lower-scale, light assembly and job-shop operations typical of LDC plants. Schonberger (1982) agrees:

> "The JIT/TQC approach seems particularly fitting in underdeveloped countries. They have the advantage of very low labor costs and no problem about too much specialization and complicated solutions. JIT/TQC is natural for the kinds of labor-intensive manufacturing that generally begin in these countries." (p. 210)

Schonberger obviously has in mind the manufacturing sector in general, and assembly industries in particular, in making his assessment of LDC applicability.

142/ See Robinson (1988) for examples of success in the introduction of JIT practices in U.S. auto subsidiaries in Mexico.

4.49 Obviously the same points, only stronger, can be made in relation to the subsidiaries of Japanese corporations that have a strong presence throughout Asia and increasingly in Latin America. One would expect these firms to have tried to introduce the same management methods they use at home.143/144/

4.50 The policy objective in relation to these firms would be to convince them that it was in their best interest to transfer the new organizational practices to their subsidiaries abroad, along with management and worker retraining and restructuring of supplier relations. However, to assess whether Japanese, U.S., and European subsidiaries are viable conduits for the transfer of the new practices, much more research is necessary.

4.51 Domestic participants in change. Various types of domestic firms in less developed countries also are potential candidates for organizational change, particularly those involved in assembly-intensive activity in sectors

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143/ This doesn't always hold true as we know that until two years ago, Nissan's Mexican plant was operated very much like a traditional U.S. plant--presumably because it was still very profitable to do this behind Mexico's tariff walls.

144/ The Maruti joint venture involving Suzuki in the production of cars in India is one of these and is qualitatively discussed by Khera and Namoto (1986). Among the problems cited are that the Japanese like to "give small doses of technology over a prolonged period of time, whereas the Indians are people in a hurry"; Japanese insistence on "cleanliness and orderliness" as a key to productivity does not come naturally to the workers; the Japanese believe in technology transfer through hands-on experience while the Indian engineers are used to learning through study and don't like to get their hands dirty; and finally where the Japanese insist on time consuming and tortuous tests of component quality carried out "in the field," the Indian government insists blindly on meeting a strict local content timetable without regard to quality or the capabilities of the suppliers.

We have learned of complaints from the government, suppliers and in the Indian press over the slow pace of technology transfer in this project and over the "exploitative" nature of Suzuki's insistence on quality which excludes Indian suppliers. Such fears are no doubt based on the experience of having worked with Western TNCs who have made a fine art of maintaining recipient dependency by spuriously enforcing quality clauses in the technology transfer contract. Our guess is that this is not what is at work here, but rather a lack of understanding on the part of the Indians of the role of quality. American suppliers and the press made exactly the same complaints about Japanese assemblers in the U.S. until the Americans learned just how far behind they were in quality! Clearly, there is much to learn from further study of the Japanese technology transfer experience.

such as motor vehicles, domestic appliances, electric motors, pumps, etc.[145]/

4.52 In the NICs (and nearly NICs)--leaving aside their significant involvement in the motor vehicle industry--engineering and, more specifically, capital goods firms are usually among the most competent and most resilient enterprises in the manufacturing sector.[146]/ In the engineering industry, export competitiveness is increasingly a crucial determinant of success. This brings firms right up against the fact that flexibility, quality, and responsiveness are key competitive elements in the international context and suggests that firms may not have a choice whether to introduce the new practices--they may simply not be able to survive unless they do.

4.53 In the most poorly developed countries, the number of domestic privately-owned firms that exhibit similar strengths to NIC firms drops off precipitously. But some firms with acceptable preconditions for organizational change can be found. UNCTAD surveyed 37 firms with more than 100 employees each and a reasonable degree of technological and managerial competence in a variety of engineering products in Tunisia, Thailand, Tanzania and Peru. Similar firms operate in both the agricultural and industrial segments of the engineering sector in many other countries.[147]/

4.54 Such a sample can include public sector enterprises operating in the engineering sector (frequently in capital goods production in the poorer countries) or purchasing significant inputs from smaller firms. These firms operate on a large scale, have a semblance of managerial and engineering

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145/ For instance, in more than 20 countries, the assembly of cars, commercial vehicles and four-wheel tractors is on a significant scale, with 30% or more local content (implying some degree of subcontractor network).

146/ For instance, a recent study by UNCTAD (1985) on capital goods production in developing countries, surveyed 87 domestically owned firms in India, South Korea, brazil and China capable of producing "complex" capital goods in the machine tools, process equipment and electrical equipment subsectors. All of these exhibited characteristics that would make them suitable participants in change efforts. they were large (number of employees ranged from 476 to 10,000), dominant in their sector (firms surveyed accounted for 70% of total output in respective subsectors), well established (their 'age' ranged from 13 to 42 years), professionally managed and technologically competent (% of engineers/R&D staff to total workforce ranged from a low of 10% in China through 25% in electrical equipment producers in India). Franzman (1982), Amsden (1985), and Jacobsson (1985) surveyed similar firms in Hong Kong, Taiwan Province and Argentina.

147/ Child and Kaneda (1975), although dated, describe an extremely robust group of small, medium and large sized diesel engine and component manufacturers in Pakistan who collectively exhibited many of the preconditions for organizational change. Thoburn (1973) and Bell and Scott-Kemmis (1980) do the same for Malaysia and Thailand, and more references could be cited.

competence, exhibit a degree of specialization, and exercise some influence over their network of suppliers.[148]

4.55 Finally, the argument is easily made that cultural factors would all but exclude some countries from adopting the new practices. However, other countries might be favorable candidates precisely because of cultural affinity for some aspects of the new practices. These countries include the NICs and other countries in Asia, particularly China, where many firms with the sort of favorable enterprise characteristics mentioned above are likely to be found--but where extensive state control of the market poses many problems. Certainly, during our own visits to Hyundai and other South Korean auto firms, we could see clear evidence that the new practices were making an important contribution.[149]

4.56 <u>Some anecdotal evidence on the application of the new practices in developing countries</u>. Fortunately, however, our case for applicability is not entirely based on speculation and <u>a priori</u> reasoning since evidence is beginning to accumulate that the new practices are being transferred to developing countries, not just in the engineering sector but in other sectors as well.

4.57 The information available is very anecdotal at this stage but demonstrates the possibilities for change among different types of firms and sectors.[150] For example, in Singapore, a Japanese subsidiary producing machine tools introduced JIT and TQC in the early 1980s. As a result, worker productivity rose by 72%. The quality of the output was sufficiently high so that 95% of its annual sales (30 million Singapore dollars) are exported to Japan, the U.S. and Europe. Another example from the same country relates to a U.S. subsidiary producing disk drives and cartridges for computers. It introduced JIT and TQC practices in 1985. Lead-time (per day) was cut by 50%, inventory reduced by over 50%, and product variety increased from four to 45 types.

148/ Public enterprise performance in all of these areas obviously varies. Brazil, Mexico, India and China boast some very successful and very dynamic enterprises (and some disasters) that could both introduce change internally and be a progressive force for restructuring and reforming the supplier network. In the poorer countries, there are fewer success stories in the public sector--so few that many may be dismantled or privatized. But where government remains committed to their survival, the pressure is now on for them to be more efficient, and, hence, public sector managers may be willing to pursue some of the new practices. The fact that many of the changes could be introduced with very low levels of investment is an additional and very important attraction that, of course, has relevance right across the types of firms we are discussing.

149/ Kerbs (1987) argues that the same is true in U.S. subsidiaries of Korean firms.

150/ Unless indicated, these examples come from unpublished research, including our ongoing work in this area funded by the Rockefeller Foundation.

4.58 It is worthwhile noting that two of the best documented examples of the successful introduction of the new practices come from Latin America--a region exhibiting significant cultural differences from Asia. The first example is a large (20,000 employees/20 factories) clothing producer in Brazil. Senior management, drawing on its knowledge of Japanese techniques and group technology concepts, has reorganized production in each plant. Groups of workers (14-22 members) cooperatively plan and carry out related sets of operations on a given output level per day. Group workers master a range of skills (with higher pay for more skills) and receive bonuses based on group, not individual, performance. Work moves through the cutting, assembly and finishing rooms on a strict JIT basis, and keeps station or buffer inventories small.

4.59 Under the system, work-in-progress inventory was eliminated completely after accounting for 30%-40% of product costs; the cycle time was reduced from weeks to hours; productivity was increased by between 200% and 400% for different tasks; and space requirements were reduced from 80 sq. ft to 30 sq. ft per workstation.[151/] This is a textbook JIT operation. The example is intriguing not just because of its Latin American origin and the results, but because few Western apparel producers have introduced organizational change on this scale.

4.60 The second example [152/] concerns a Venezuelan engineering firm that began introducing organizational change in the early 1980s. Productivity has increased by 25%, along with improvements in other areas (shown below), all achieved with virtually no capital investment.

Table 4.1: PRODUCTIVITY INCREASES IN AN ENGINEERING FIRM

	1981	1986
Scrap	0.43%	0.23%
Customer returns (returns/hundred units sold)	0.46%	0.11%
Labor productivity (standard units produced per man hour)	6.44	8.32

Source: Hoffman (1988).

151/ Gaetan (1986).

152/ Given by Bessant and Rush (1987).

4.61 There is also evidence that institutional mechanisms are being put into place in some countries to facilitate the diffusion of knowledge of the new practices. In Brazil, a small, private, non-profit training institute, INAM (the National Institute of Management) now specializes in the provision of consultancy and training services for the new practices. In Venezuela, a program backed by the Andean Pact has been set up to provide similar services for Venezuelan firms; it includes consultancy advice on automation technologies. Not surprisingly, the Japanese government, through its development aid schemes, is supporting a large number of training programs aimed at upgrading the skills of managers in developing country firms. The precise content of these programs is not clear from the information available to us, but it seems logical that Japanese management practices would form the model for any training provided.

4.62 One cannot generalize from the above examples, of course--particularly since there are also indications from literature and ongoing research that problems have been encountered by foreign firms trying to introduce the practices to their subsidiaries.[153/] On top of this is the reality that the development experience is littered with examples of North-South "technology" transfer--involving both embodied and disembodied technology--which has failed either because of the vast cultural differences or because sufficient care was not taken to adapt new ideas to the very different conditions that exist. Nevertheless, the fact that successful introduction has been accomplished in some cases suggests that at the very least the question of applicability remains an open issue.

4.63 Structural constraints revisited. In these last comments, we return to some points about the existence of severe internal and external structural constraints on the introduction of organizational change in the LDCs. Some Latin American firms have adapted to the mass-production-oriented international division of labor in a way that suggests they are well-placed to introduce the new organizational practices.[154/]

153/ Fukuda (1988) indicates that Japanese service sector firms have had particular problems transferring their management culture to their Asian subsidiaries. However, the analysis is qualitative and heavily influenced by the comparative management literature and does not yield general conclusions.

154/ Sabel (1986). In developing his analysis--where the main concern is in fact with the prospects of Latin American firms introducing flexible automation--Sabel draws in an original way on the work of Katz and others in the well-known BID/CEPAL project. The results of this project are reviewed in Katz (1980 and 1982). Related references can be found in Dahlman and Westphal (1982); Bell, (1982); Nelson (1979); and Teitel (1979 and 1981).

4.64 We expand this argument to include three components.

(i) Latin American firms originally set up along mass-production lines have been forced to adapt to a variety of market constraints in a way that means they are now "systematically different from comparative firms in the advanced countries. Whereas the latter organize operations sequentially on the model of the assembly line...the former are organized as a collection of semi-autonomous shops under one roof. Each shop specializes in a particular manufacturing operation or the production of a certain family of parts; similar machines or clusters of machines are thus grouped together rather than dispersed in sequences defined by the steps required to build a particular product."155/

(ii) Although the subcontractor network in Latin America and elsewhere is poorly developed, possibilities exist, as happened in Singapore (and, we would add, South Korea and Taiwan), where Japanese and American machine-tool builders created an efficient supplier network almost from nothing.156/ New assembler-supplier relations suggest a better way of organizing supplier relations in the less developed countries where supplier quality is low. Final assemblers could, in principle, take an active role in developing and upgrading supplier capability, particularly for quality and reliability. This means foregoing for awhile the well known benefits of purchasing abroad, but the returns in terms of an upgrading of the supplier network could be considerable.

(iii) The severe crisis in demand experienced by the Latin American engineering sector in the early 1980s forced many of these firms to experiment with different forms of production organization and,

155/ Sabel, p. 46. Thus, one sees here firms that may already have laid the basis for organizational change and who we know from the additional work of Dahlman, Teitel and others, have accumulated an impressive set of technical skills suited to the sort of continuous incremental innovation that is an essential component of the new practices.

156/ See Franzman (1984) for the positive side and Amsden (1977, 1985) for the difficulties. We would add that the informal metal working sector in many countries exhibits characteristics of flexibility resilience and great ingenuity that are necessary attributes of supplier networks that have been created in Japan to serve large firms in the auto and other sectors. In developing countries, such firms, and their links to formal sector customers, could be strengthened considerably if large firms and governments actively sought to assist and encourage their development a la the Japanese model instead of competing against them and trying to tax and legislate them out of existence.

in short, to become more flexible in their deployment of resources.[157]

4.65 At this stage, it is of course impossible to confirm or deny Sable's speculations and our extension of them. However, the questions he raises prompt us to consider anew the nature of some of the constraints mentioned earlier.

4.66 Looking again at the skill and competence issue. Among the most problematic of these are the low skill and competence levels of management and workforce. It takes time for an economy and an education system to create competent managers, technically proficient engineers, and skilled production workers. Currently there are massive training efforts underway throughout the developing world and in industrialized countries.[158] This is positive and will help close the skills gap.[159]

4.67 We can make a related point about the skill differences between workers operating under the old approach to production and those under the new practices. The latter workers may appear much more highly skilled than production workers elsewhere, particularly those in developing countries, but this is a misreading of the nature of their skills. The main difference is that they are multi-skilled in typical production line jobs and are thus able to perform a larger variety of tasks than are workers operating under Fordist relations of production.

4.68 Workers under the new conditions are trained, paid and allowed to do jobs that line workers elsewhere are not permitted to do. These restrictions on the latter have nothing to do with their skill level or ability to learn but with management's choice not to give them the necessary training and responsibility. Inevitably, the number of entrants into the labor pool who have the basic skills and education to become candidates for multi-skill training is very limited--and this will remain a severe constraint for a long while. But in the particular case of the engineering sector, existing workers are, by definition, from the pool of competent people who in fact do have the ability to learn. They may not have been given the training or the opportunity to fulfill their productive potential--the critical policy problem is how to get management to invest in their upgrading.

157/ This process has been well documented in Porteous (1987) who looked at the efforts of Brazilian machine tool producers to survive the drastic 1980-84 period where demand for their products dropped by nearly 70% overall, and yet many firms survived and have emerged even stronger. Sabel suggests on the basis of the Brazilian experience, that such "crisis-tested" firms would make good candidates to adopt the new practices.

158/ See Kubr and Wallace (1984) for a review.

159/ However, it should be clear that the substance of what is taught in the courses is as important as the number of people being trained. Management trainees will be ill-served if they are not introduced to best practice management, as discussed in this paper.

4.69 <u>Other constraints reexamined</u>. Scarcities of raw materials and imported inputs, while acting as a constraint on output, should also alert managers to the financial value of economizing on their use, for reducing waste in general, and for eliminating defects in particular. Many of the new practices, even introduced on a piecemeal basis, directly attack these problems and should be attractive to developing country managers and entrepreneurs.

4.70 Similarly, the predominance of old, low-volume machines in many developing country engineering firms is often cited in the literature as a constraint on output and productivity growth. So too is the fact that small size--often mandated by government policy--has prevented firms from pursuing both product specialization and internal specialization of tasks, such as quality control. This has forced managers, engineers and production workers to perform work for which they haven't been trained. The same negative perspective comes out in more recent concerns that the low cost of labor will inhibit developing country firms from investing in expensive automation technology. It is possible to reinterpret each one of these "constraints" and find potentially positive reasons for the introduction of the new practices.

4.71 "Filtering" conventional views about the problems of production in developing countries through an analytical framework informed by an understanding of the new principles and practices results in surprising insights. We would venture the hypothesis that one of the reasons why some Western firms have had difficulties with the new practices is precisely because of scale factors, because their own production organization is hopelessly overcomplicated, and because they have large sunk investments in elaborate, high cost and complex machinery. In Third World plants where scale is lower, the process more labor intensive, and product flows much less complex, principles that emphasize simplicity as the key to productivity improvement might even be easier to implement than in the advanced industrial countries.

4.72 The same logic applies to developing an entirely new set of production relations between management and workers in a context where neither group is as well educated or trained as their counterparts in advanced countries. In the absence of a mass production tradition, and with only limited Fordist relations of production, might it not be easier to introduce the new relations into what are essentially "greenfield" sites?

4.73 The questions raised above, having to do with the possibilities and the problems associated with introduction of the new approaches to production organization and management in developing countries, have wide-ranging implications. For instance, much conventional wisdom underpinning mainstream industrialization literature on technology and industrial development needs to be reconsidered.[160] On the research side, the efforts of domestic firms in developing countries to apply these ideas, and the efforts of Western and Japanese TNCs to transfer them to their subsidiaries, need to be examined.

4.74 In the area of policy, the evidence and arguments given above indicate many aspects that need to be reexamined--for example, the scale of resources devoted to management training and the substance of that training; the nature of existing incentive programs designed to encourage new investment in fixed capital; direct foreign investment and technology transfer policies; local content policies; the underlying assumptions about attainable productivity and output levels, and export prospects, under liberalization.

4.75 Thus the agenda for thought, research and action is extensive and provocative. It is hoped that this paper will stimulate further exploration--by a wider audience--of the issues raised by the emergence of the new practices and their possible introduction in developing countries.

160/ Since this field is the author's main concern, the issue is worthy of some provocative speculation. It seems to us that many concepts that are conventional wisdom in the technology and development literature and from which we derive policy implications and proposals need to be thoroughly reexamined through a new lens. We include here such cherished ideas as the nature of "learning" within Third World firms, the importance of incremental technical change and "capacity stretching", distinctions between "technological" capacity and "productive" capacity, the constituents of technological "mastery", the importance of organizing the technology transfer process to maximize access to core technological knowhow, etc.
Some of these concepts may have to be discarded or completely redefined --such as the distinction between productive and technological capacity and the notions of mastery, which pay lip service to the importance of operational skills but really see the main source of productivity growth as a firm's technical change capacity as distinct from its operational skills. One of the implications of the process and organizational change reviewed in this paper is that these distinctions no longer many any sense in theory or in practice and that firms, particularly, those in the Third World, should concentrate on developing the right form of production organization and operational skills so crucial to the technical change process. Likewise, the failure of the technology and development literature to grasp fully the importance of management skills _per se_ is now shown to be grossly at variance with the reality of some of the most important examples of industrial development. The literature has to grapple fully with the implications of the Japanese experience, and with the fact that the Japanese "model" is now defining industrial best-practice. It is clear that the new organizational paradigm has some fundamental and challenging implications for the way problems of industrial production, technology transfer and competitiveness in the Third World are characterized and for the policy implications derived from that analysis.

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